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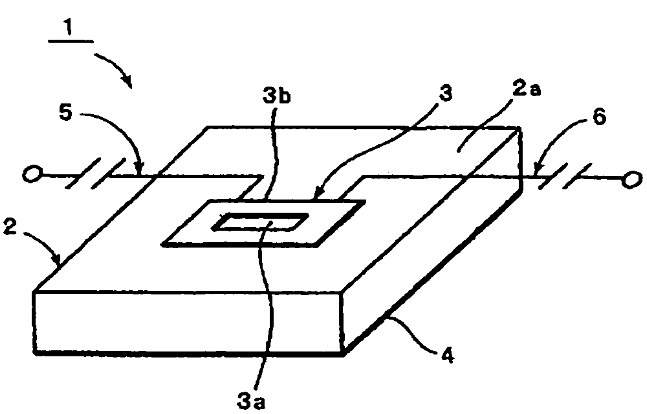
# (54) Dual mode band-pass filter

(57) A dual mode band-pass filter includes a metallic film (3) for constituting a resonator, formed on the first main face (2a) of a dielectric substrate (2) having first and second main faces (2a), or inside of the dielectric substrate (2), an opening (3a) formed in the metallic film (3), at least one ground electrode (4) formed on the second main face of the dielectric substrate (2) or inside of the dielectric substrate (2), so as to be opposed to the metallic film (3) through a dielectric layer, and a pair of input-output coupling circuits (5,6) connected to the metallic film (3).

Fig. 1



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## Description

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

[0001] The present invention relates to a dual mode band-pass filter for use in, e.g., a communication equipment operating in the range of the microwave band to the milliwave band.

#### 2. Description of the Related Art

[0002] Conventionally, different types of dual mode band-pass filters have been proposed as a band-pass filter for use in a high frequency band as described in MINIATURE DUAL MODE MICROSTRIP FILTERS, J. A. Curtis and S. J. Fiedziuszko, 1991 IEE MTT-S Digest, and so forth.

[0003] FIGS. 48 and 49 are schematic plan views illustrating conventional dual mode band-pass filters, respectively.

[0004] In a band-pass filter 200 shown in FIG. 48, a circular conductive film 201 is formed on a dielectric substrate (not shown). Input-output coupling circuits 202 and 203 are coupled to the conductive film 201 so as to form an angle of 90° to each other. A tip-open stub 204 is formed on the conductive film 201 at the position thereof forming a central angle of 45° to the input-output coupling circuit 203. Thereby, two resonance modes with different resonance frequencies are coupled. Thus, the band-pass filter 200 is configured so as to operate as a dual mode band-pass filter.

[0005] In a dual mode band-pass filter 210 shown in FIG. 49, a substantially square conductive film 211 is formed on a dielectric substrate. Input-output coupling circuits 212 and 213 are connected to the conductive film 211 so as to form an angle of 90° to each other. The corner of the conductive film 211 in the position thereof forming an angle of 135° with respect to the input-output coupling circuit 213 is cut away. The resonance frequencies in two resonance modes are made different from each other by the formed the cut portion 211a, so that the two resonance modes are coupled to each other. Thus, the band-pass filter 210 can be operated as a dual mode band-pass filter.

[0006] On the other hand, there has been proposed a dual mode band-pass filter which contains a ring-shape conductive film instead of the circular conductive film (Japanese Unexamined Patent Application Publication No. 9-139612 and No. 9-162610, and so forth). In particular, a dual mode filter is disclosed, in which a ring-shaped ring transmission line is used, input-output coupling circuits are arranged so as to form a central angle of 90° similarly to the dual mode band-pass filter 200 shown in FIG. 48, and a tip-open stub is provided in a part of the ring transmission line.

[0007] Moreover, Japanese Unexamined Patent Application Publication No. 6-112701 discloses a dual mode band-pass filter which uses a ring transmission line similar to the above-mentioned transmission line. As shown in FIG. 50, in the dual mode filter 221, a ring resonator is formed in which a ring conductive film 222 is formed on a dielectric substrate. In this case, four terminals 223 to 226 are formed on the ring conductive film 222 so as to form an angle of 90° to each other with respect to the center of the ring conductive film 222. Two of the four terminals arranged at the positions forming an angle of 90° to each other with respect to the center of the ring conductive film are connected to input-output coupling circuits 227 and 228, respectively. The remaining two terminals 225 and 226 are connected to each other via a feedback circuit 230.

[0008] Moreover, it is described that in the ring resonator comprising one strip line and having the above-described configuration, orthogonal resonance modes, not coupled to each other, are generated, and the coupling degree is controlled by means of the above-mentioned feedback circuit 230.

[0009] In the conventional dual mode band-pass filters shown in FIGS. 48 and 49, a two step band-pass filter can be formed by forming one conductive film pattern. Accordingly, the band-pass filter can be miniaturized.

[0010] However, the dual mode band-pass filters each have the configuration in which the input-output coupling circuits, separated from each other by an particular angle, are coupled to each other in the circular or square conductive film pattern. Therefore, the dual mode band-pass filters have the disadvantage that the coupling degree cannot be increased, and a wide pass band can not be attained.

[0011] In the band-pass filter shown in FIG. 48, the conductive film 201 is restricted substantially onto a circular shape. In the band-pass filter shown in FIG. 49, the conductive film 211 is also limited to a substantially square shape. There is the problem that the design flexibility is low.

[0012] Dual mode band-pass filters 221 using such a ring resonator as described in Japanese Unexamined Patent Application Publication Nos. 9-139612 and 9-162610 have the problem that it is difficult to enhance the coupling degree, and the shape and size of the ring resonator are restricted.

[0013] On the other hand, in the dual mode band-pass filter 221 described in Japanese Unexamined Patent Application Publication No. 6-112701, the coupling degree is controlled, and the band-width can be widened by use of the feedback circuit 230. However, in the dual mode filter described as the conventional technique, the feedback circuit 230 is required. Thus, there is caused the problem that the circuit configuration becomes complicated. Furthermore,

problematically, the shape and size of the ring resonator is limited to a ring-shape, so that the design flexibility becomes low.

## SUMMARY OF THE INVENTION

[0014] Accordingly, it is an object of the present invention to provide a dual mode band-pass filter in which the above-described problems of the conventional technique are solved, the miniaturization can be performed, the coupling degree can be enhanced, the coupling degree can be easily adjusted, a wide pass band can be realized, and the design flexibility is high.

[0015] To achieve the above object, according to the present invention, there is provided a dual mode band-pass filter which comprises a dielectric substrate having first and second main faces, a metallic film having an opening for coupling two resonance modes and formed in the first main face of the dielectric substrate or inside of the dielectric substrate, at least one ground electrode formed on the second main face of the dielectric substrate or inside of the dielectric substrate, so as to be opposed to the metallic film through a dielectric layer, and a pair of input-output coupling circuits connected to different parts of the metallic film. With the above-described configuration, one of the two resonance modes, that is, one propagated in parallel to the imaginary straight line passing through the connection points at which a pair of the input-output coupling circuits are connected to the metallic film, and the other propagated perpendicularly to the imaginary line, is affected by the opening so that the resonance frequency is varied. In other words, the opening is formed so as to exert an influence over the resonance current of one of the resonance modes whereby the one resonance mode can be coupled to the other resonance mode. Thus, the opening causes the two resonance modes to be coupled to each other, and the filter can be operated as a dual mode band-pass filter.

[0016] Preferably, the opening has a shape containing a long-size direction and a short-size direction.

[0017] Also preferably, the plan shape of the opening is a rectangle, an ellipse, or a shape comprising a rectangle or ellipse having a bent part thereof elongating in a direction intersecting the long-size direction.

[0018] Yet preferably, the plan shape of the opening is a rectangle, a rhombus, a regular polygon, a circle, or an ellipse.

[0019] Plural openings may be formed.

[0020] Preferably, the metallic film is formed on the first main face of the dielectric substrate, and the ground electrode is formed on the second main face.

[0021] Also preferably, the metallic film is formed on a height level inside of the dielectric substrate, and the ground electrodes are formed on the first and second main faces of the dielectric substrate, whereby the band-pass filter has a tri-plate structure.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

FIG. 1 is a perspective view of a dual mode band-pass filter according to a first embodiment of the present invention;
FIG. 2 is a schematic plan view showing the major part of the dual mode band-pass filter of the first embodiment;
FIG. 3 is a graph showing the frequency characteristics of the dual mode band-pass filter of the first embodiment;
FIG. 4 is a graph showing the frequency characteristics of a resonator produced by forming a rectangular metallic film having no opening on a dielectric substrate;
FIG. 5 is a graph showing the frequency characteristics of a dual mode band-pass filter formed in a concrete experimental example of the first embodiment, in which the size of the metallic film is 15 × 7 mm, the length of an opening is 6 mm, and the width of the opening is 0.2 mm;
FIG. 6 is a graph showing the frequency characteristics of the dual mode band-pass filter formed in the concrete experimental example of the first embodiment, in which the size of the metallic film is 15 × 7 mm, the length of the opening is 8 mm, and the width of the opening is 0.2 mm;
FIG. 7 is a graph showing the frequency characteristics of the dual mode band-pass filter formed in the concrete experimental example of the first embodiment, in which the size of the metallic film is 15 × 7 mm, the length of the opening is 10 mm, and the width of the opening is 0.2 mm;
FIG. 8 is a graph showing the frequency characteristics of the dual mode band-pass filter formed in the concrete experimental example of the first embodiment, in which the size of the metallic film is 15 × 7 mm, the length of the opening is 12 mm, and the width of the opening is 0.2 mm;
FIG. 9 is a graph showing the frequency characteristics of the dual mode band-pass filter formed in a concrete experimental example of the first embodiment, in which the size of the metallic film is 15 × 7 mm, the length of the opening is 13.5 mm, and the width of the opening is 0.2 mm;
FIG. 10A is a cross sectional view of a dual mode band-pass filter according to a first modification example of the first embodiment;

FIG. 10B is a schematic plan view showing the main part of a dual mode band-pass filter according to a second modification example of the first embodiment;

FIG. 11 is a graph showing the frequency characteristics of the dual mode band-pass filter of the second example of the first embodiment;

FIG. 12 is a schematic plan view of a dual mode band-pass filter according to a third modification example of the first embodiment;

FIG. 13 is a graph showing the frequency characteristic of the dual mode band-pass filter of the third modification example of the first embodiment;

FIG. 14 is a perspective view showing the appearance of a dual mode band-pass filter according to a second embodiment of the present invention;

FIG. 15 is a schematic plan view showing the main part of the dual mode band-pass filter of the second embodiment;

FIG. 16 is a graph showing the frequency characteristics of the dual mode band-pass filter of the second embodiment;

FIG. 17 is a schematic plan view of a dual mode band-pass filter according to a first modification example of the second example;

FIG. 18 is a graph showing the frequency characteristics of the dual mode band-pass filter of the first modification example of the second embodiment;

FIG. 19 is a schematic plan view of a dual mode band-pass filter according to a third embodiment of the present invention;

FIG. 20 is a graph showing the frequency characteristics of the dual mode band-pass filter of the third embodiment;

FIG. 21 is a schematic plan view of a dual mode band-pass filter according to a fourth embodiment of the present invention;

FIG. 22 is the frequency characteristics of the dual mode band-pass filter of the fourth embodiment;

FIG. 23 is a schematic plan view of a dual mode band-pass filter according to a first modification example of the fourth embodiment;

FIG. 24 is a graph showing the frequency characteristics of the dual mode band-pass filter of the first modification example of the fourth embodiment;

FIG. 25 is a schematic plan view of a dual mode band-pass filter according to a second modification example of the fourth embodiment;

FIG. 26 is a graph showing the frequency characteristics of the dual mode band-pass filter of the second modification example of the fourth embodiment;

FIG. 27 is a schematic plan view of a dual mode band-pass filter according to a third modification example of the fourth embodiment;

FIG. 28 is the frequency characteristics of the dual mode band-pass filter of the third modification example of the fourth embodiment;

FIG. 29 is a perspective view of a dual mode band-pass filter according to a fifth embodiment of the present invention;

FIG. 30 is a schematic plan view showing the main part of the dual of the fifth embodiment;

FIG. 31 is a graph showing the frequency characteristics of the dual mode band-pass filter of the fifth embodiment;

FIG. 32 is a schematic plan view showing a dual mode band-pass filter according to a first modification example of the fifth embodiment;

FIG. 33 is a graph showing the frequency characteristics of the dual mode band-pass filter of the first modification example of the fifth embodiment;

FIG. 34 is a schematic plan view of a dual mode band-pass filter according to a second modification example of the fifth embodiment;

FIG. 35 is a graph showing the frequency characteristics of the dual mode band-pass filter of the second modification example of the fifth embodiment;

FIG. 36 is a perspective view of a dual mode band-pass filter according to a sixth embodiment of the present invention;

FIG. 37 is a schematic plan view showing the main part of the dual mode band-pass filter of the sixth embodiment;

FIG. 38 is a graph showing the frequency characteristics of the dual mode band-pass filter of the sixth embodiment;

FIG. 39 is a schematic plan view of a dual mode band-pass filter according to a first modification example of the sixth embodiment;

FIG. 40 is a graph showing the frequency characteristics of the dual mode band-pass filter of the first modification example of the sixth embodiment;

FIG. 41 is a schematic plan view of a dual mode band-pass filter according to a second modification example of the sixth embodiment;

FIG. 42 is a graph showing the frequency characteristics of the dual mode band-pass filter of the second modifi-

cation example of the sixth embodiment;

FIG. 43 is a perspective view of a dual mode band-pass filter according to a seventh embodiment of the present invention;

FIG. 44 is a schematic plan view showing the main part of the dual mode band-pass filter of the seventh embodiment;

FIG. 45 is the frequency characteristics of the dual mode band-pass filter of the seventh embodiment;

FIG. 46 is a schematic plan view of a dual mode band-pass filter according to a first modification example of the seventh embodiment;

FIG. 47 is a graph showing the frequency characteristics of the dual mode band-pass filter of the first modification example of the seventh embodiment;

FIG. 48 is a schematic plan view showing an example of a conventional dual mode band-pass filter;

FIG. 49 is a schematic plan view showing another example of the conventional dual mode band-pass filter; and

FIG. 50 is a schematic plan view showing yet another example of the conventional dual mode band-pass filter.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0023]** Hereinafter, concrete embodiments of the present invention will be described to make more apparent the present invention.

**[0024]** FIG. 1 is a perspective view of a dual mode band-pass filter according to a first embodiment of the present invention. FIG. 2 is a schematic plan view of the dual mode band-pass filter;

**[0025]** A dual mode band-pass filter 1 contains a rectangular sheet dielectric substrate 2. In this embodiment, the dielectric substrate 2 is made of a fluororesin having a dielectric constant εr of 2.58. However, in this and below-described embodiments, as dielectric materials for forming the dielectric substrate, appropriate dielectric materials such as $BaO$-$Al_2O_3$-$SiO_2$ type ceramics or the like can be used, in addition to the fluororesin.

**[0026]** The thickness of the above-described dielectric substrate 2 has no particular limitations. In this embodiment, the thickness is set at 350 μm.

**[0027]** A metallic film 3 is formed on the upper face 2a of the dielectric substrate 2 to produce a resonator. The metallic film 3 is formed in a partial area on the dielectric substrate 2, and takes a rectangular shape with long and short sides in this embodiment. An opening 3a is formed in the metallic film 3. The opening 3a has a rectangular plane shape similar to that of the metallic film 3a. The lengthwise direction (long-side direction) of the opening 3a is parallel to the longitudinal direction, namely, the long-side direction, of the metallic film 3.

**[0028]** In this embodiment, the length W of each long side of the metallic film 3 is 15 mm, and the length L of each short side is 7 mm. For the opening 3a, the length w of each long side is 13.5 mm, and the length 1 of each short side is 0.2 mm. However, the sizes of the metallic film 3 and the opening 3a are not limited to the above values. The shapes of the metallic film 3 and the opening 3a can be modified, correspondingly to desired center frequency and bandwidth.

**[0029]** On the other hand, a ground electrode 4 is formed on the whole of the under face of the dielectric substrate 2.

**[0030]** Input-output coupling circuits 5 and 6 are connected to one of the long sides 3b of the metallic film 3, respectively. The input-output coupling circuits 5 and 6, not limited to the positions shown in FIG. 1, may be connected in appropriate positions on the metallic film 3, provided that the positions are different from each other on the metallic film 3.

**[0031]** In the dual mode band-pass filter of this embodiment, an input voltage is applied between one of the input-output coupling circuits 5 and 6 and the ground electrode 4, whereby a predetermined output power between the other circuit of the input-output coupling circuits 5 and 6 and the ground electrode 4 is output. In this case, the two resonance modes are coupled to each other, since the metallic film 3 has a rectangular shape, and the opening 3a is formed. Thus, this filter operates as a dual mode band-pass filter. FIG. 3 shows the frequency characteristics of the dual mode band-pass filter 1 of this embodiment.

**[0032]** In FIG. 3, the reflection characteristic is represented by solid line A, and the transmission characteristic is done by broken line B (hereinafter, these characteristics will be represented in the same manner). As seen in FIG. 3, a band-pass filter is formed in which the band indicated by arrow C is uses as a transmission band.

**[0033]** In particular, it is seen that in the dual mode band-pass filter of this embodiment, the two resonance modes are coupled to each other, due to the opening 3a formed in the metallic film 3, whereby characteristics suitable for the dual mode band-pass filter can be obtained.

**[0034]** By changing the shape of the metallic film 3 in the above-described configuration, various resonance characteristics of the two modes can be obtained. This will be described in reference to a concrete experimental example.

**[0035]** Metallic films 3 made of copper, having a rectangular plane shape, and eliminating the opening 3a, which had different sizes as listed in TABLE 1, were formed on the dielectric substrate. Thereby, four types of resonators were prepared. In TABLE 1, reference character W represents the length of a long side of the metallic film 3, and reference character L represents the length of a short side thereof.

**[0036]** As resonance modes based on the resonators comprising these metallic films, the following two modes are

probable. A first resonance mode is $\lambda/2$ resonance mode (resonance frequency $fr_1$) of which the resonator length is the length in the long-side direction of the metallic film 3. A second resonance mode is a $\lambda/2$ resonance mode (resonance frequency $fr_2$) of which the resonator length is the length in short-side direction of the metallic film 3.

[0037] The measurements and calculation values of the resonance frequencies $fr_1$ and $fr_2$ are listed in the following TABLE 1.

[0038] The frequency characteristic of the metallic film 3 with W × L = 15 × 13 mm, eliminating the opening, is illustrated as a typical example in FIG. 4.

[TABLE 1]

| W × L(mm) | measurements | | calculation values | |
|---|---|---|---|---|
| | $fr_1$(GHz) | $fr_2$(GHz) | $fr_1$(GHz) | $fr_2$(GHz) |
| 15 × 13 | 6.29 | 7.13 | 6.22 | 7.18 |
| 15 × 11 | 6.22 | 8.63 | 6.22 | 8.48 |
| 15 × 9 | 6.16 | 10.51 | 6.22 | 10.37 |
| 15 × 7 | 6.22 | 13.24 | 6.22 | 13.33 |

[0039] As seen in TABLE 1, the measurements and the calculation values are substantially coincident with each other. In the above-described results, it is seen that the resonator formed by use of the rectangular metallic film 3 has two resonance modes, that is, one resonance mode is $\lambda/2$ resonance in which the resonator length is the length W of a long side of the metallic film 3, and the other resonance mode is $\lambda/2$ resonance in which the resonator length is the length of a short side of the metallic film 3.

[0040] Hereinafter, it will be described that by forming the opening 3a in the rectangular metallic film 3, the above-mentioned two resonance modes can be coupled, whereby a dual mode band-pass filter can be obtained.

[0041] Five types of resonators were prepared in which openings 3a with a width 1 of 0.2 mm and lengths W of 6, 8, 10, 12, and 13.5 mm were formed in a resonator containing the rectangular metallic film 3 with a size W × L of 15 × 7 mm prepared in the above experimental example.

[0042] FIGS. 5 to 9 show the frequency characteristics of the five types of the resonators.

[0043] As seen in FIGS. 5 to 9, the larger the length W of the opening 3a becomes, the more the resonance frequency $fr_2$ of the second resonance mode shifts to the low frequency side. Furthermore, as seen in FIG. 9, when the resonance frequency $fr_2$ becomes lower than the resonance frequency $fr_1$, the resonance frequencies $fr_1$ and $fr_2$ couple together, whereby a band-pass filter is formed.

[0044] Presumably, in the dual mode band-pass filter of this embodiment, the resonance current in the resonance mode propagated in the short-side direction is partially interrupted in the opening 3a, so that the resonance current acts as if an inductance were added, and therefore, the resonance frequency $fr_2$ in the resonance mode propagated in the short-side direction is reduced. In other words, in the dual mode band-pass filter of this embodiment, the respective resonance currents flow differently from each other in the two resonance modes in the rectangular metallic film. Accordingly, for the purpose of coupling the two resonance modes as described above, the opening 3a is formed in such a manner that the resonance frequency in one of the resonance modes approaches the resonance frequency in the other resonance mode.

[0045] As described above, the opening 3a is formed in such a manner that the two resonance modes can be coupled together. That is, when the resonator comprising the rectangular metallic film 3 is used, the lengthwise direction of the opening 3a is provided along the long side direction of the metallic film 3, and moreover, the size in the widthwise direction of the opening 3a is selected so that the resonance frequency in the resonance mode propagated in the short side direction of the metallic film 3 is reduced to approach the resonance frequency in the resonance mode propagated in the long side direction of the opening 3a.

[0046] Accordingly, as described above, the filter can be operated as a dual mode band-pass filter, and moreover, the coupling degree can be controlled freely and significantly by adjusting the size of the opening 3a.

[0047] FIG. 10A is a cross sectional view of a first modification example of the dual mode band-pass filter according to a first embodiment of the present invention.

[0048] In the first embodiment, the metallic film 3 is formed on the upper face of the dielectric substrate 2. In the dual mode band-pass filter of the first modification example shown in FIG. 10A, the metallic film 3 having the opening 3a is formed inside of the dielectric substrate 2. The plane shape of the metallic film 3 is similar to that of the first embodiment.

[0049] Furthermore, ground electrodes 4 and 4 are formed on the whole of the upper and under faces of the dielectric substrate 1. Accordingly, the dual mode band-pass filter of this modification example has a tri-plate structure. Thus, the dual mode band-pass filter of the present invention may have the tri-plate structure.

[0050] It is not necessary to form the ground electrodes 4 on the whole of the faces of the dielectric substrate 2, provided that the ground electrodes 4 are opposed to each other through the metallic film 3 and the dielectric substrate 2 or through a part of the layers of the dielectric substrate 2. In addition, the ground electrodes 4 may be formed in the form of internal electrodes at the middle in height of the dielectric substrate 2.

[0051] FIG. 10B is a schematic plan view of a second modification example of the dual mode band-pass filter according to the first embodiment of the present invention.

[0052] In the dual mode band-pass filter 1 of the first embodiment, the input-output coupling circuits 5 and 6 are connected to one of the long sides of the rectangular metallic film 3. However, as shown in FIG. 10, the input-output coupling circuits 5 and 6 are connected to the first and second long sides 3b and 3c, respectively. The other configuration is the same as that of the first embodiment.

[0053] FIG. 11 shows the frequency characteristics of the dual mode band-pass filter of this modification example having the same configuration as the dual mode band-pass filter 1 of the first embodiment excepting that the connection points of the input-output coupling circuits 5 and 6 of this modification example are different from those of the first embodiment. As seen in FIG. 11, in this modification example, characteristics suitable for a band-pass filter to be operated in a high frequency band can be obtained. In particular, by comparing FIG. 3 with FIG. 11, it is seen that the band-width can be considerably varied by changing the connection-point positions of the input-output coupling circuits 5 and 6. That is, the adjustment amount of the band-width and the design flexibility can be enhanced.

[0054] FIG. 12 is a schematic plan view of a third modification example of the dual mode band-pass filter of the first embodiment. In this modification example, regarding the metallic film 3, the length of a long side is set at 15 mm, and that of a short side is set at 13 mm. In other respects, the band-pass filter of this modification example is configured similarly to that of the first embodiment.

[0055] FIG. 13 shows the frequency characteristics of the dual mode band-pass filter of the second modification example. As seen in the comparison of FIG. 3 with FIG. 13, the bandwidth can be varied by changing the length of the short side of the metallic film 3.

[0056] FIG. 14 is a perspective view of a dual mode band-pass filter according to a second embodiment of the present invention. FIG. 15 is a schematic plan view showing the main part of the dual mode band-pass filter.

[0057] The dual mode band-pass filter 11 of the second embodiment is configured similarly in the same manner as that of the first embodiment excepting that the shape of a metallic film 13 formed on the upper face of the dielectric substrate 2 is different from that of the metallic film 3 of the first embodiment. Accordingly, similar parts are designated by the same reference numerals, and the repeated description is omitted.

[0058] In the dual mode band-pass filter of the present invention, the shape of the metallic film constituting a resonator is not limited to a rectangle. That is, as shown in FIG. 14, the peripheral edge may have a random contour, that is, may have an optional contour. Also in this case, by forming an opening 13a in the metallic film 13 having an optional shape, and connecting the input-output coupling circuits 5 and 6 to two parts of the metallic film 13, a dual mode band-pass filter can be formed.

[0059] A concrete experimental example and the frequency characteristic of the dual mode band-pass filter 11 will be described. The dielectric substrate 2 made of the same material and having the same thickness as that of the first embodiment. Moreover, the metallic film 13 made of a copper film with a thickness of 18 μm and having an optional shape with a maximum diameter of 15 mm was prepared. A ground electrode was formed on the under face of the dielectric substrate 2 similarly to that of the first embodiment.

[0060] Referring to the connection points of the input-output coupling circuits 5 and 6, two optional points in the periphery of the metallic film 13 are selected as shown in FIGS. 14 and 15. The opening 13a is formed so as to be in parallel to the straight line passing through the two points.

[0061] FIG. 16 shows the frequency characteristics of the dual mode band-pass filter of the second embodiment.

[0062] As seen in FIG. 16, two resonance modes are coupled to each other, whereby a frequency characteristic suitable for a dual mode band-pass filter can be obtained. That is, even if the shape of the metallic film 13 is optional, the filter can be operated as a dual mode band-pass filter similarly to that of the first embodiment, by adjusting the length of the rectangular opening 13a.

[0063] In the second embodiment, the shape of the metallic film 13 is optional, and moreover, the positional relations of the input-output coupling circuits 5 and 6 to the metallic film 13 are optional. That is, it is not necessary that the connection points of the input-output coupling circuits 5 and 6 are arranged so as to form an angle of 90° to each other with respect to the center of the metallic film 13.

[0064] In the dual mode band-pass filter 11 of the second embodiment, the opening 13a has a rectangular shape of which the length of a long side 11.5 mm and the length of a short side is 0.2 mm. The shape and size of the opening 13a are not limited to the above shape and values. As seen in the description of the first example, the opening in the dual mode band-pass filter of the present invention is formed so as to couple two resonance modes. In this case, the resonance frequencies of the two resonance modes are different from each other, depending on the shape of the metallic film and the positions of the connection points of the input-output coupling circuits 5 and 6. Therefore, the

shape and size of the opening 13a for coupling the two modes are changed correspondingly to the above-mentioned shape and the positions.

[0065] That is, the shape and size of the opening 13a in the second embodiment are varied, depending on the shape and size of the metallic film 14 and the positions of the connection points of the input-output coupling circuits 5 and 6. Therefore, the shape and size of the opening 13a can be concretely determined, correspondingly to the above-mentioned shape and positions.

[0066] However, as seen in the description of the first embodiment, the opening 13a is formed so as to be in parallel to the imaginary straight line passing through the connection points of the input-output coupling circuits 5 and 6. The opening 13a interferes the resonance current caused by the resonance propagating in the perpendicular direction to the imaginary straight line passing through the above-mentioned connection points, whereby the two resonance modes are coupled. Accordingly, as seen in the experimental example of the first embodiment, the two resonance modes can be securely coupled by adjusting the size in the lengthwise direction of the opening 13a, provided that two optional points in the periphery of the metallic film 13 are selected as the connection points, and the opening 13a is formed in parallel to the straight line passing through the two points. In other words, the opening 13a is formed so that the lengthwise direction of the opening 13a is in parallel to the imaginary straight line passing through the connection points of the input-output coupling circuits. Moreover, the length of the opening 13a is selected so that the two resonance modes, caused by the shape of the metallic film 13, can be coupled.

[0067] FIG. 17 is a schematic plan view of a first modification example of the dual mode band-pass filter 11 of the second embodiment. In this modification example, the metallic film 13 and the opening 13a having the same shape and size of the second embodiment is formed. However, the connection points of the input-output coupling circuits 5 and 6 of this modification example are different from those of the second embodiment. That is, the connection points of the input-output coupling circuits 5 and 6 are arranged in the positions opposed to each other on the outer side of the part of the metallic film 13 where the opening 13a is formed, in the perpendicular direction to the lengthwise direction of the opening 13a. The other configuration is similar to that of the second embodiment.

[0068] FIG. 18 shows the frequency characteristic of the dual mode band-pass filter of the above-described modification example.

[0069] By comparing FIG. 16 with FIG. 18, it is seen that the bandwidth of the band-pass filter of the second embodiment is 1390 MHz, and the bandwidth of the band-pass filter of the first modification example is 490 MHz. That is, the bandwidths are equal to 20 % and 6.5 % of the center frequencies of the band-pass filters, respectively, are obtained. Thus, it is seen that by changing the positions of the connection points of the input-output coupling circuits 5 and 6, the bandwidth can be varied, and the coupling degree can be changed.

[0070] FIG. 19 is a schematic plan view of a dual mode band-pass filter according to a third embodiment of the present invention. In a dual mode band-pass filter 21 of the third embodiment, a metallic film 23 constituting a resonator takes a circular shape. A rectangular opening 23a is formed in the metallic film 23. It is not necessary that the connection points of the input-output coupling circuits 5 and 6 are provided in such positions as to form an center angle of 90° with respect to the circular metallic film 23.

[0071] FIG. 20 shows the frequency characteristic of the band-pass filter of the third embodiment shown in FIG. 19. The characteristic shown in FIG. 20 is obtained when the circular metallic film 23 has a diameter of 15 mm, and a rectangular opening 23a with the length of a long side of 5 mm and the length of a short side of 0.2 mm is formed at a position shifted from the center of the metallic film 23. The other sizes are the same as those of the first embodiment.

[0072] As seen in FIG. 20, in the third embodiment, a dual mode band-pass filter can be also formed by using the circular metallic film 23a, and forming the opening 23a. In particular, in the case of the metallic film is circular, and the rectangular opening 23a is formed so that the lengthwise direction of a long side of the opening 23a is substantially in parallel to the imaginary line passing through the connection points of the input-output coupling circuits 5 and 6, the resonance current in the resonance mode propagated in the perpendicular direction to the imaginary line, not the resonance current in the resonance mode propagated substantially in parallel to the imaginary line, is affected by the opening 23a, though a circle has an isotropic shape, whereby the two resonance modes are coupled to form a dual mode band-pass filter.

[0073] FIG. 21 is a schematic plan view of a dual mode band-pass filter according to a fourth embodiment of the present invention. In the dual mode band-pass filter of the fourth embodiment, a metallic film 33 constituting a resonator has a square shape. A rectangular opening 33a is formed in the metallic film 33. The input-output coupling circuits 5 and 6 are connected to two points in the periphery of the metallic film 33. It is not necessary that the connection points of the input-output coupling circuits 5 and 6 are positioned so as to form a center angle of 90° with respect to the center of the square metallic film 33.

[0074] FIG. 22 shows the frequency characteristics of the band-pass filter of the fourth embodiment shown in FIG. 21. The characteristics shown in FIG. 22 are obtained when the side length of the square metallic film 33 is 15 mm, and the opening 33a of with the length of a long side of 6 mm and that of a short side of 0.2 mm is formed in the square metallic film 33 at a position shifted from the center of the rectangular metallic film 33. The other sizes are the same

as those of the first embodiment.

[0075] As seen in FIG. 22, also in the third embodiment, a dual mode band-pass filter can be formed by use of the square metallic film 33, attributed to the formation of the opening 33a.

[0076] FIG. 23 is a schematic plan view of a first modification example of the dual mode band-pass filter of the fourth embodiment. In the fourth embodiment, one opening 33a is formed. However, plural openings 33a and 33b may be formed, as shown in FIG. 23. FIG. 24 shows the frequency characteristic of a modification example of the band-pass filter shown in FIG. 23. The opening 33b has the same size as the opening 33a. The openings 33a and 33b are arranged in parallel to each other at an interval of 2 mm. The other sizes are the same as those of the fourth embodiment.

[0077] FIG. 25 is a schematic plan view of a second modification example of the band-pass filter of the fourth embodiment. FIG. 26 shows the frequency characteristic. In the dual mode band-pass filter of the second modification example, an opening 33c is formed in a metallic film 33. The opening 33c has bent parts $33c_1$ and $33c_1$ which are bent in the perpendicular direction to the lengthwise direction of the opening 33a (fourth embodiment) at both ends thereof. FIG. 26 shows the frequency characteristics obtained where the length of each bent part is set at 0.7 mm.

[0078] As seen in FIGS. 25 and 26, the opening 33a is not limited to a rectangular shape and may take the shape in which the above-mentioned bent parts $33c_1$ and $33c_1$ are provided at both ends of a rectangle.

[0079] FIG. 27 is a schematic plan view of a third modification example of the dual mode band-pass filter of the fourth embodiment. FIG. 28 shows the frequency characteristics thereof. In the dual mode band-pass filter of the third modification example, a cross-shaped opening 33d is formed in the metallic film 33. The shape of the cross-shaped opening 33d corresponds to two rectangular openings crossed at a right angle, one rectangular opening thereof having a long-side length of 7 mm and a short-side length of 0.2 mm, the other rectangular opening having a long-side length of 4 mm and a short-side length of 0.2 mm. As seen in FIGS. 27 and 28, in the case in which the cross-shaped opening 33d is formed, a dual mode band-pass filter can be also formed similarly to the fourth embodiment.

[0080] As seen in the first to the third modification examples of the fourth embodiment, in the dual mode band-pass filter of the present invention, plural openings may be provided, and not only a rectangular opening but also an opening having bend parts, and moreover, a cross-shaped opening may be employed. That is, the shape of the opening has no especial limitations. In addition to the above-mentioned different types of shapes such as rectangles and deformed rectangles, ellipses, circles, and so forth can be optionally used. Furthermore, shapes such as ellipses or the like, excluding rectangles, which have bent parts connected thereto as described above are available. A filter containing any of the above openings can be operated as a dual mode band-pass filter by adjusting the shape and size of the opening, similarly to the filter of each of the first to fourth embodiments. Desirably, the opening has a symmetric shape in the resonance direction of at least one of the two resonance modes.

[0081] FIG. 29 is a perspective view of a dual mode band-pass filter according to the fifth embodiment of the present invention. FIG. 30 is a schematic plan view showing the major part of the band-pass filter. FIG. 31 shows the frequency characteristics of the band-pass filter.

[0082] In the dual mode band-pass filter 41 of the fifth embodiment, a metallic film 43 constituting a resonator is formed so as to have a triangular shape. In the other respects, the dual mode band-pass filter 41 is similar to that of the first embodiment.

[0083] A ground electrode 4 is formed on the same dielectric substrate 2 as that of the first embodiment. The equilaterally triangular metallic film 43 with the length of one side of 21 mm is formed. An opening 43a with the length of a long side of 10 mm and that of a short side of 0.2 mm is formed. The input-output coupling circuits 5 and 6 are connected to the different sides of the metallic film 43 at the positions thereof which are shifted from the opening 43a. The input-output coupling circuits 5 is not limited to the connection points shown in FIGS. 29 and 30. That is, it is not necessary that the input-output coupling circuits 5 and 6 are arranged so that the connection points form a center angle of 90° with respect to the center of the metallic film 43. Thus, the design flexibility can be enhanced.

[0084] As shown in FIG. 31, in the case of the metallic film 43 having the equilaterally triangular shape, the filter can be also operated as a dual mode band-pass filter similarly to the band-pass filter of each of the first to fourth embodiments.

[0085] In the fifth embodiment, the metallic film 43 has an equilateral triangle. It is not necessary that the shape of the metallic film 43 is an equilateral triangle. The metallic film 43 may be formed in an optional isosceles triangle.

[0086] FIG. 32 is a schematic plan view of a first modification example of the dual mode band-pass filter of the fifth example. FIG. 33 shows the frequency characteristics of the modification example. The dual mode band-pass filter of the first modification example is formed in the same manner as that of the fifth embodiment excepting that the plan shape of the metallic film 43 is the right isosceles triangle of which the vertical angle is 90°, and the length of the base is 21 mm. As seen in FIGS. 32 and 33, in the use of the metallic film 43 having the right triangle, the band-pass filter can be operated as a dual mode band-pass filter by forming an opening 43a, and connecting the input-output coupling circuits 5 and 6 to two parts of the metallic film 43.

[0087] FIG. 34 is a schematic plan view showing a second modification example of the dual mode band-pass filter of the fifth embodiment. FIG. 35 is a graph showing the frequency characteristics of the band-pass filter.

[0088] In the second modification example, the metallic film 43 having an isosceles triangular shape of which the vertical angle is 120° and the base length is 21 mm is formed. In the other respects, the band-pass filter is the same as that of the fifth embodiment. As seen in FIGS. 34 and 35, in the second modification example, the filter can be also operated as a dual mode band-pass filter.

[0089] According to the present invention, two resonance modes can be coupled to form dual mode band-pass filters by forming the above-described openings in different types of isosceles triangles, adjusting the sizes of the openings, and connecting the input-output coupling circuits to different parts of the triangles, as seen in the fifth embodiment, and the first and second modification examples of the fifth embodiment.

[0090] FIG. 36 is a perspective view showing the appearance of a dual mode band-pass filter 51 according to a sixth embodiment of the present invention. FIG. 37 is a schematic plan view of the band-pass filter. FIG. 38 is a graph showing the frequency characteristics of the band-pass filter.

[0091] In a dual mode band-pass filter 51 of the sixth embodiment, a metallic film 52 has a rhomboid shape. In the other respects, the band-pass filter 1 is the same as that of the first embodiment. A dielectric substrate and a ground electrode similar to those of the first embodiment were used, and a metal films 53 having a rhomboid shape with diagonal line lengths of 21 mm and 8 mm was formed. Furthermore, an opening 53a having a long-side length of 14 mm and a short-side length of 0.2 mm was formed in the metallic film 53. The input-output coupling circuits 5 and 6 were connected to the two different sides of the metallic film 53. As seen in FIG. 38, in this dual mode band-pass filter, the two resonance modes can be also coupled to each other, and a characteristic suitable for the dual mode band-pass filter can be obtained, attributed to the above-described configuration.

[0092] In the dual mode band-pass filter of the present invention, the metallic film constituting a resonator may take a rhomboid shape as seen in the sixth embodiment.

[0093] FIG. 39 is a schematic plan view showing a first modification example of the dual mode band-pass filter of the sixth embodiment, and FIG. 40 is a graph showing the frequency characteristics thereof. In the dual mode band-pass filter of the first modification example, the connection points of the input-output coupling circuits 5 and 6 are different from those in the sixth embodiment. That is, the input-output coupling circuits 5 and 6 are connected to a metallic film 53 so as to be opposed to each other, in the perpendicular direction to the long diagonal line of the metallic film. In the other respects, the pass-band filter is the same as that of the sixth embodiment.

[0094] As seen in FIGS. 39 and 40, in the dual mode band-pass filter of the first modification example, the two resonance modes can be coupled to each other. Furthermore, by comparing the frequency characteristics shown in FIGS. 39 and 40, it is seen that the bandwidth can be considerably varied by changing the connection points of the input-output coupling circuits 5 and 6.

[0095] FIG. 41 is a schematic plan view of a second modification example of the dual mode band-pass filter of the sixth embodiment, and FIG. 42 is a graph showing the frequency characteristic of the pass-band filter.

[0096] In the dual mode band-pass filter of the second modification example, the metallic film 53 has a rhomboid shape different from that in the sixth embodiment. In the dual mode band-pass filter of the second modification example, the rhomboid shape of the metallic film 53 is different from that in the sixth embodiment. That is, the metallic film 53 is formed so as to have a rhomboid shape having diagonal line lengths of 21 mm and 12 mm. In the other respects, the band-pass filter is the same as that of the sixth embodiment.

[0097] By comparing the characteristics shown in FIGS. 38 and 42, it is seen that the bandwidth can be changed by changing the short diagonal line of the rhombus.

[0098] When a resonator is formed by use of a metallic film having a rhomboid shape, as described above, the bandwidth can be considerably varied by changing the rhomboid shape.

[0099] FIG. 43 is a perspective view showing the appearance of a dual mode band-pass filter according to a seventh embodiment of the present invention, and FIG. 44 is a schematic plan view thereof.

[0100] In the dual mode band-pass filter of the seventh embodiment, a metallic film 63 constituting a resonator takes a regular pentagonal shape. In the other respects, the configuration of the band-pass filter is the same as that in the first embodiment. FIG. 45 shows the frequency characteristics of the dual mode band-pass filter formed in the same manner as the experimental example of the first embodiment, excepting that a regular pentagon with a side-length of 9.5 mm is formed as the above-mentioned metallic film 63.

[0101] As seen in FIG. 45, in the case of the metallic film 63 having a regular pentagonal shape, the two resonance modes can be also coupled by adjusting the size of an opening 63a, whereby the band-pass filter can be operated as a dual mode band-pass filter.

[0102] FIG. 46 is a schematic plan view showing the major part of a first modification example of the dual mode band-pass filter according to the seventh embodiment of the present invention, and FIG. 47 is the frequency characteristics thereof.

[0103] In the seventh embodiment, the metallic film 63 takes a regular pentagonal shape. In the present invention, the shape of the metallic film is not limited to a regular pentagon. The metallic film may take a regular-hexagonal shape as presented in this modification example. Regarding the dual mode band-pass filter of the modification example shown

In FIG. 46, the metallic film 63A was formed so that it took a regular hexagon with a side-length of 7.5 mm, and the other sizes of the band-pass filter were the same as those in the seventh embodiment. The frequency characteristic was measured. FIG. 47 shows the results.

[0104] In the case of the metallic film 63A with a regular hexagonal shape, constituting a resonator, the two resonance modes can be coupled to each other, and the device can be operated as a dual mode band-pass filter, as seen in FIG. 47.

[0105] In the dual mode band-pass filter of the present invention, the metallic film for constituting a resonator is formed on the dielectric substrate, and the size of the opening is adjusted, whereby the two resonance modes can be coupled to each other without the positions of the connection points of the input-output coupling circuits having no especial limitations, and a characteristic suitable for a dual mode band-pass filter can be obtained. In a conventional dual mode band-pass filter, the shape of the metallic film for constituting a resonator has a limitation, and the positions of the connection points of the input-output coupling circuits have a limitation. On the other hand, the dual mode band-pass filter of the present invention eliminates such limitations. Thus, the design flexibility can be considerably enhanced.

[0106] Moreover, the band-width can be significantly adjusted by changing the size of the metallic film, the size of the opening, and the positions of the connection points of the input-output coupling circuits. Thus, a dual mode band-pass filter having a desired band-width can be easily provided.

[0107] Preferably, according to the present invention, the opening has such a plan shape as to contain a long-size direction and a short-size direction. In this case, the resonance current produced perpendicularly to the long-size direction is interrupted by the opening. The resonance frequency of the resonance propagated perpendicularly to the long-size direction of the opening can be easily changed. Thereby, the two resonance modes can be securely coupled to each other.

[0108] In the dual mode band-pass filter of the present invention, the opening and the plan shape of the metallic film have no especial limitations, respectively. Dual mode band-pass filters having different shapes of openings and metallic films can be provided. For example, as the opening, a rectangle, an ellipse, a shape comprising a rectangle or ellipse having a bent part thereof elongating in a direction intersecting the long-size direction, or a cross shape can be optionally employed. Similarly, for the metallic film, a rectangle, a rhombus, a regular polygon, a circle, an ellipse, or an optional shape of which the periphery has an irregular shape.

[0109] In the present invention, preferably, plural openings may be formed. The band-width can be adjusted by changing the number of the openings.

[0110] In the dual mode band-pass filter of the present invention, the metallic film and the ground electrode may be formed either on the surface of the dielectric substrate or inside thereof. In the case of the configuration in which the metallic film is formed on the first main face of the dielectric substrate, and the ground electrode is formed on the second main face thereof, the dual mode band-pass filter of the present invention can be simply formed by forming conductive films on both surfaces of a dielectric substrate, respectively.

[0111] Furthermore, in the case of the tri-plate structure, radiation from the metallic film can be prevented. Thus, the loss of the band-pass filter can be reduced.

## Claims

1. A dual mode band-pass filter comprising a dielectric substrate (2) having first and second main faces (2a),

   a metallic film (3;13;23;33;43;53;63;63a) =1 having an opening (3a;13a;23a;33a;33b;33c;43a;53a;63a) =2 for coupling two resonance modes and formed in the first main face (2a) of the dielectric substrate (2) or inside of the dielectric substrate (2),
   at least one ground electrode (4) formed on the second main face of the dielectric substrate (2) or inside of the dielectric substrate (2), so as to be opposed to the metallic film (1) through a dielectric layer, and
   a pair of input-output coupling circuits (5,6) connected to different parts of the metallic film (1).

2. A dual mode band-pass filter according to claim 1, wherein the opening (2) has a plan shape containing a long-size direction and a short-size direction.

3. A dual mode band-pass filter according to claim 2, wherein the plan shape of the opening (2) is a rectangle, an ellipse, or a shape comprising a rectangle or ellipse having a bent part thereof elongating in a direction intersecting the long-size direction.

4. A dual mode band-pass filter according to any of claims 1-3, wherein the plan shape of the metallic film (1) is a rectangle, a rhombus, a regular polygon, a circle, or an ellipse.

5. A dual mode band-pass filter according to any of claims 1-4, wherein plural openings (33a,33b) are formed.

6. A dual mode band-pass filter according to any of claims 1-5, wherein the metallic film (1) is formed on the first main face (2a) of the dielectric substrate (2), and the ground electrode (4) is formed on the second main face.

7. A dual mode band-pass filter according to any of claims 1-5, wherein the metallic film (3) is formed on a height level inside of the dielectric substrate (2), and the ground electrodes (4) are formed on the first and second main faces of the dielectric substrate (2), whereby the band-pass filter has a tri-plate structure.

8. A dual mode band-pass filter according to any of claims 1 to 7, wherein the two resonance modes have resonance directions crossing at a right angle.

9. A dual mode band-pass filter according to claim 8, wherein the two resonance modes have different resonance frequency each other.

Fig. 1

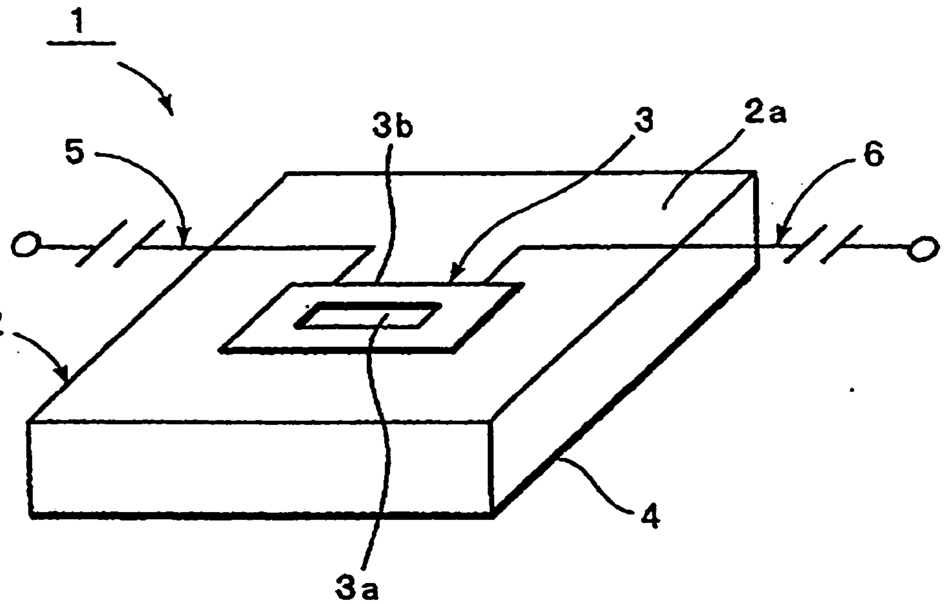
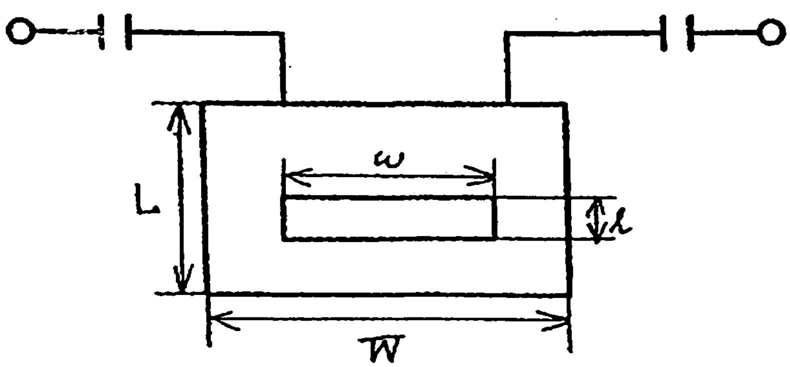



Fig. 2



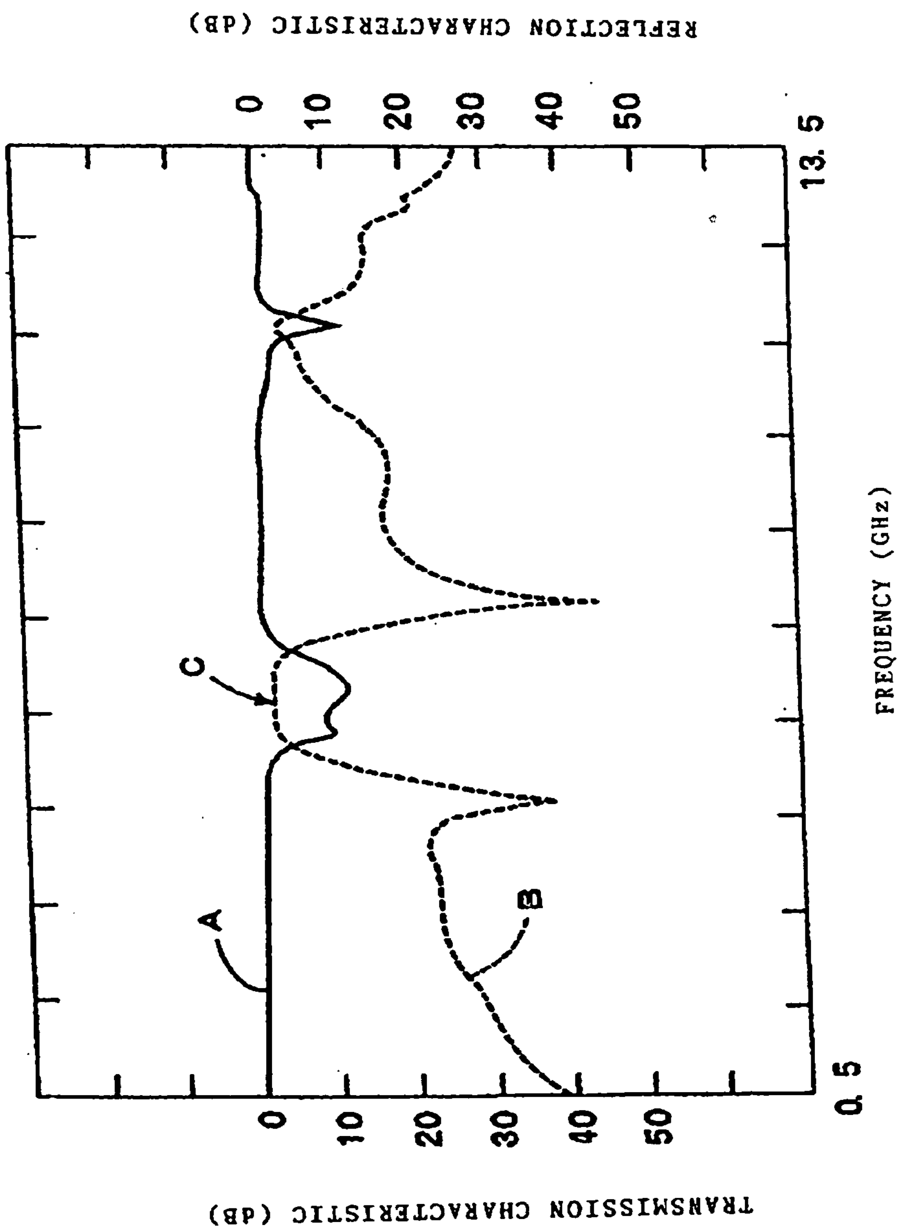

REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
13.5
A
B
C
FREQUENCY (GHz)
0.5
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig. 3

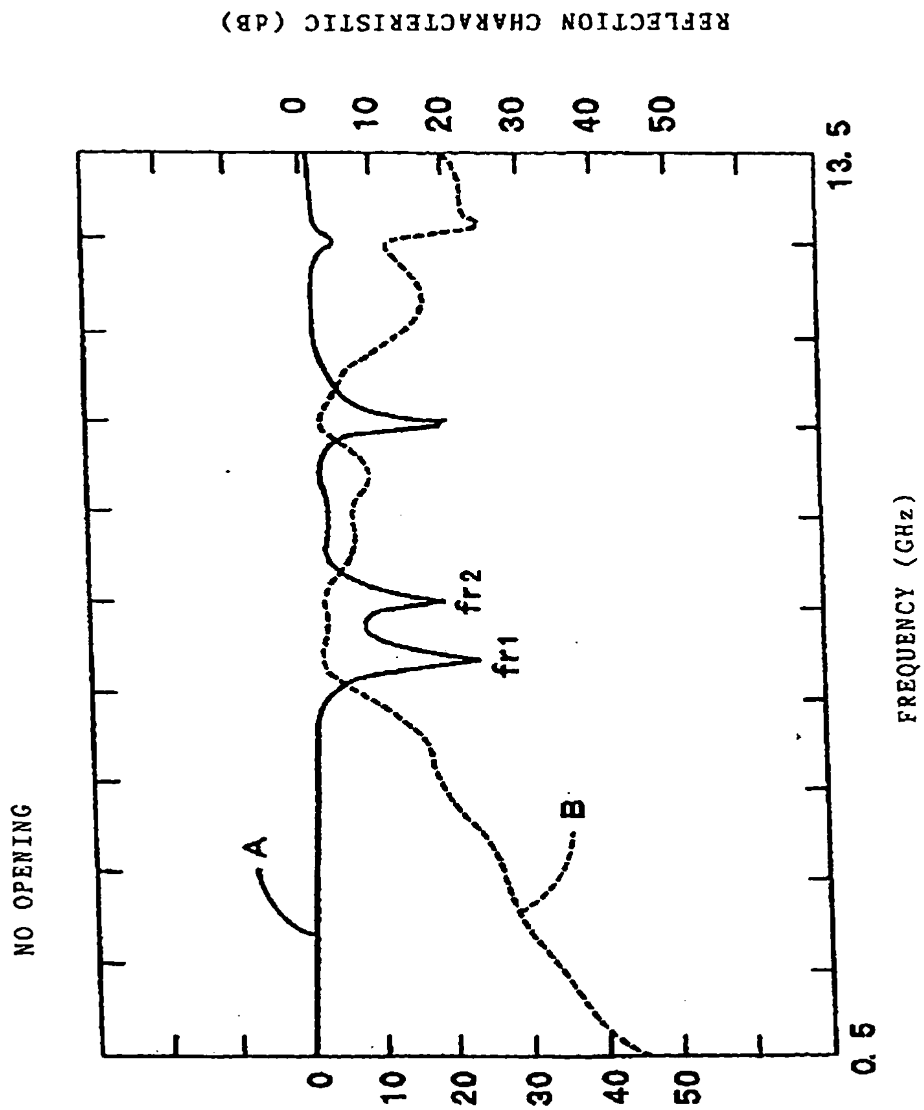

NO OPENING
REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
13. 5
A
B
fr1
fr2
FREQUENCY (GHz)
0. 5
TRANSMISSION CHARACTERISTIC (dB)

Fig. 4

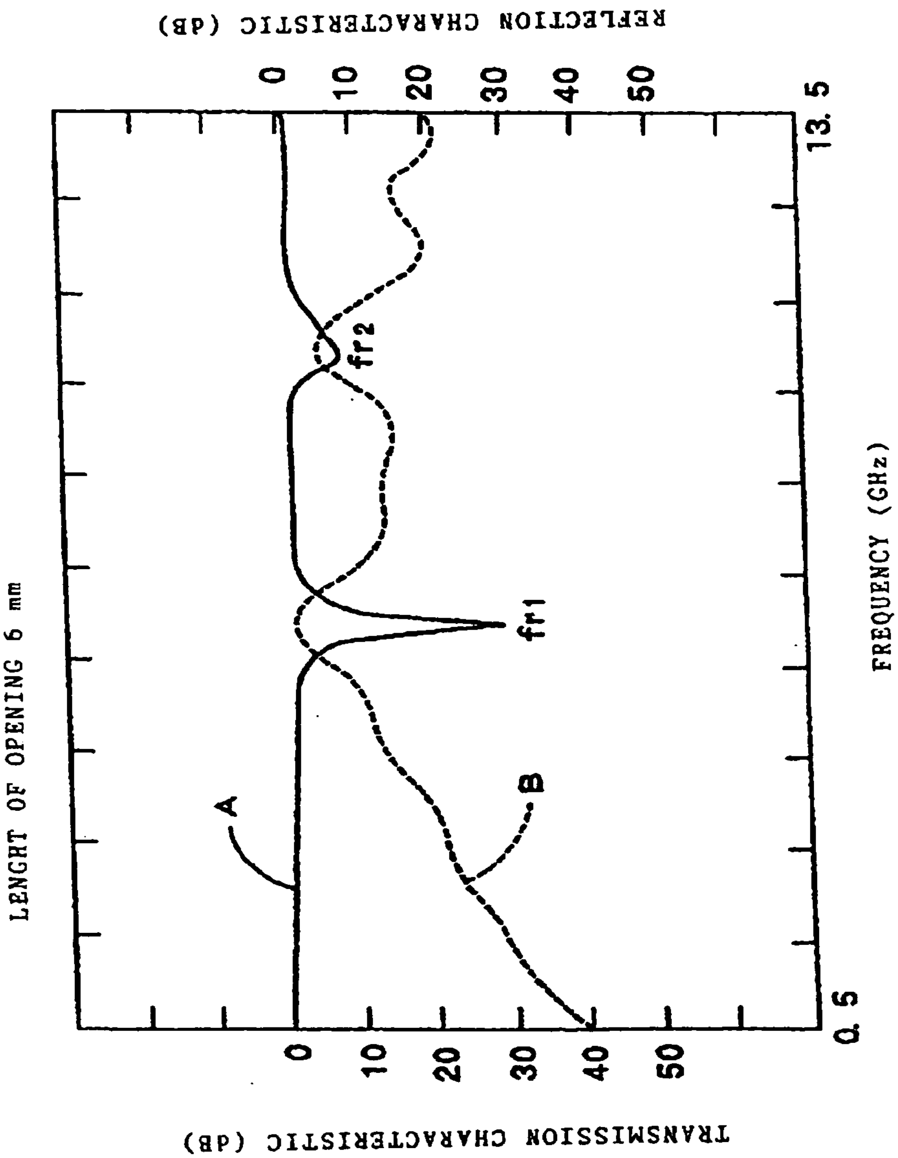

LENGHT OF OPENING 6 mm
REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)
0
10
20
30
40
50
FREQUENCY (GHz)
0.5
13.5
A
B
fr1
fr2

Fig. 5

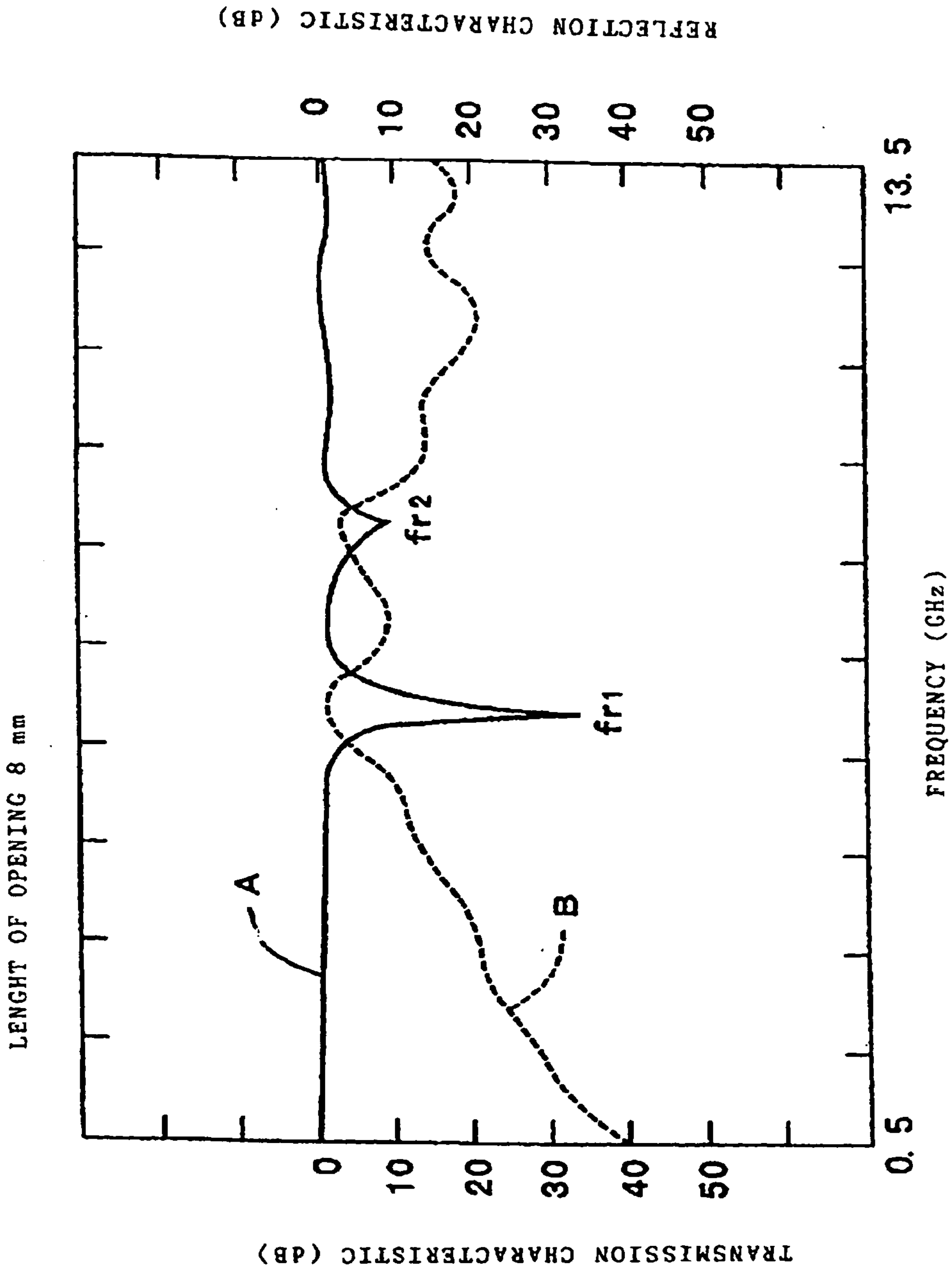

LENGHT OF OPENING 8 mm
REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)
0
10
20
30
40
50
FREQUENCY (GHz)
0. 5
13. 5
A
B
fr1
fr2

Fig. 6

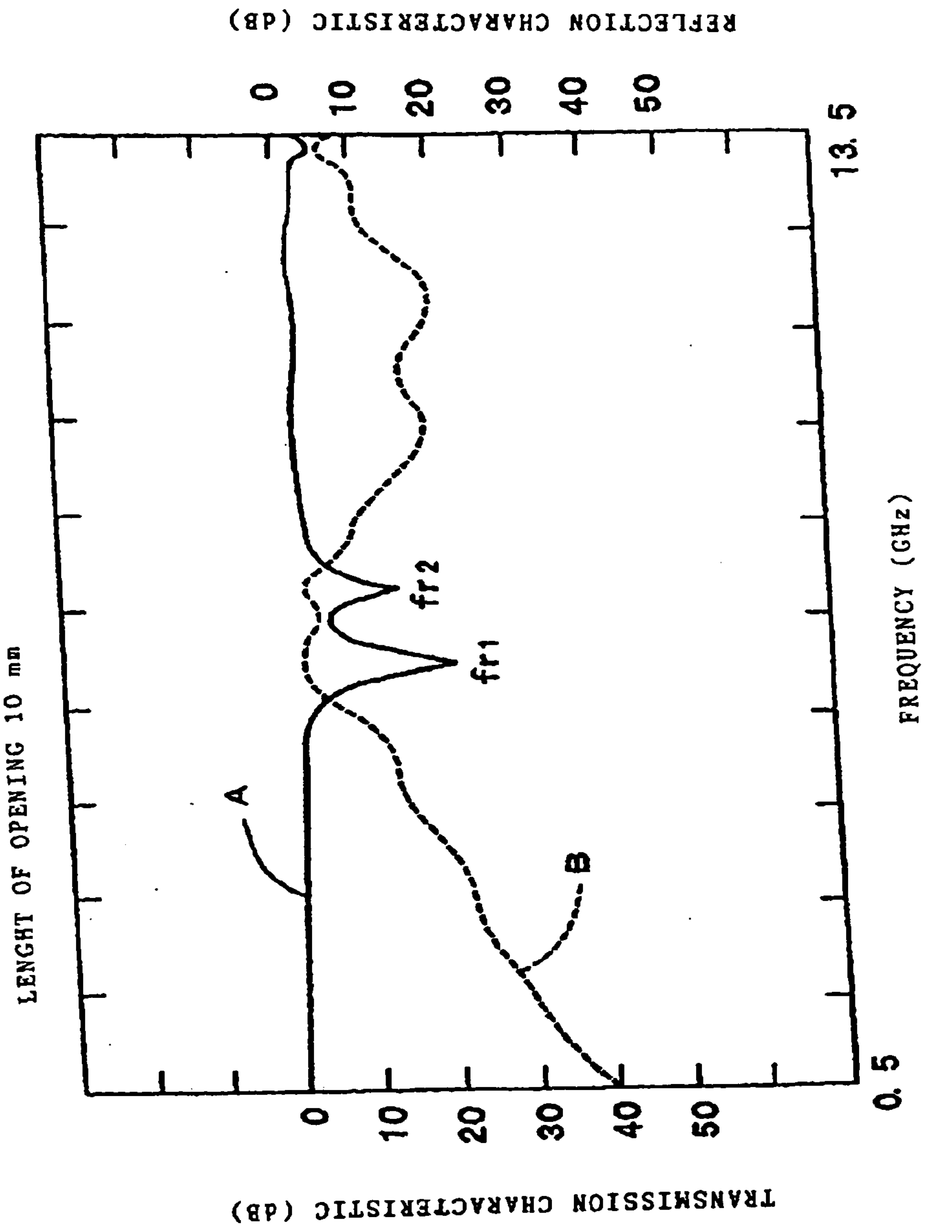

LENGHT OF OPENING 10 mm
REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
13.5
0.5
FREQUENCY (GHz)
fr1
fr2
A
B
TRANSMISSION CHARACTERISTIC (dB)
0
10
20
30
40
50

Fig. 7

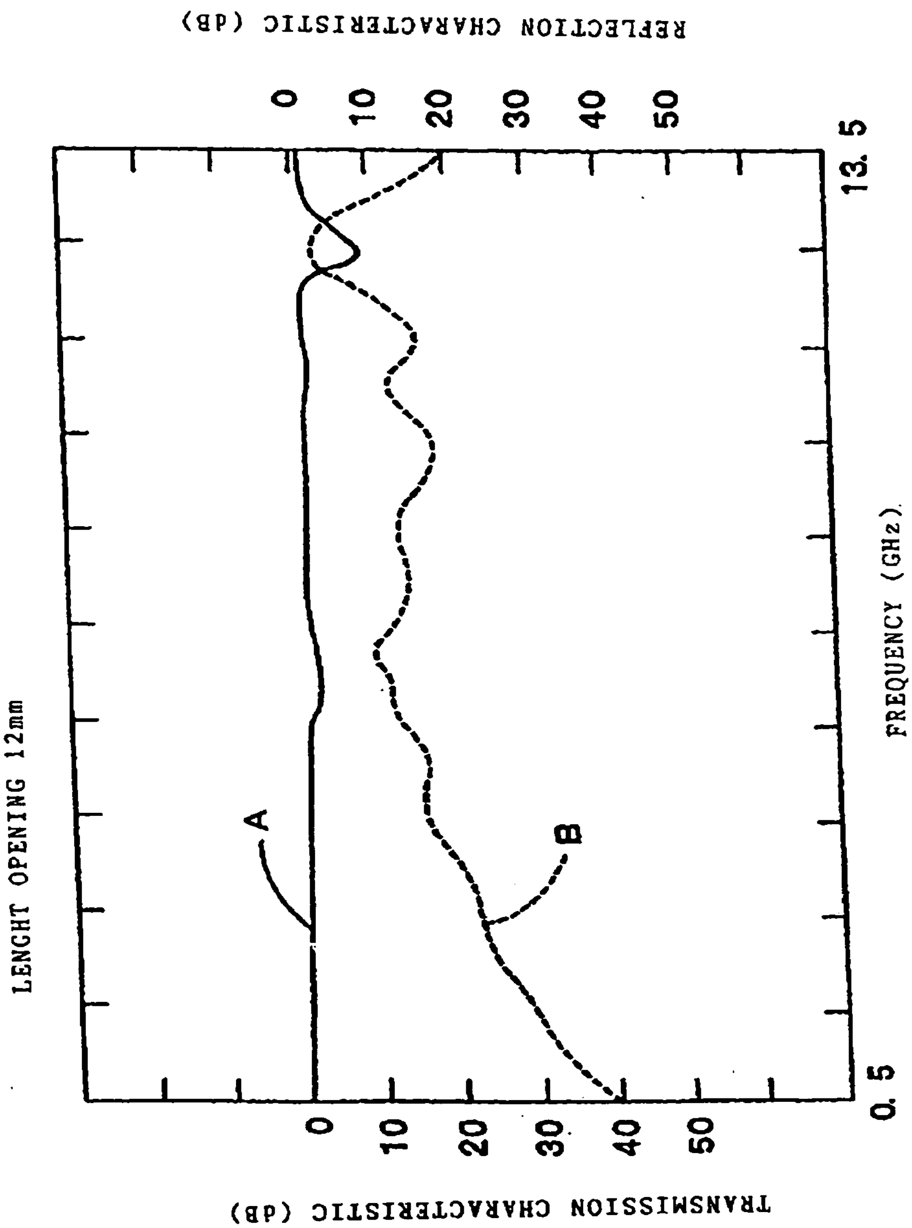

LENGHT OPENING 12mm
REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
13.5
0.5
A
B
FREQUENCY (GHz)
TRANSMISSION CHARACTERISTIC (dB)

Fig. 8

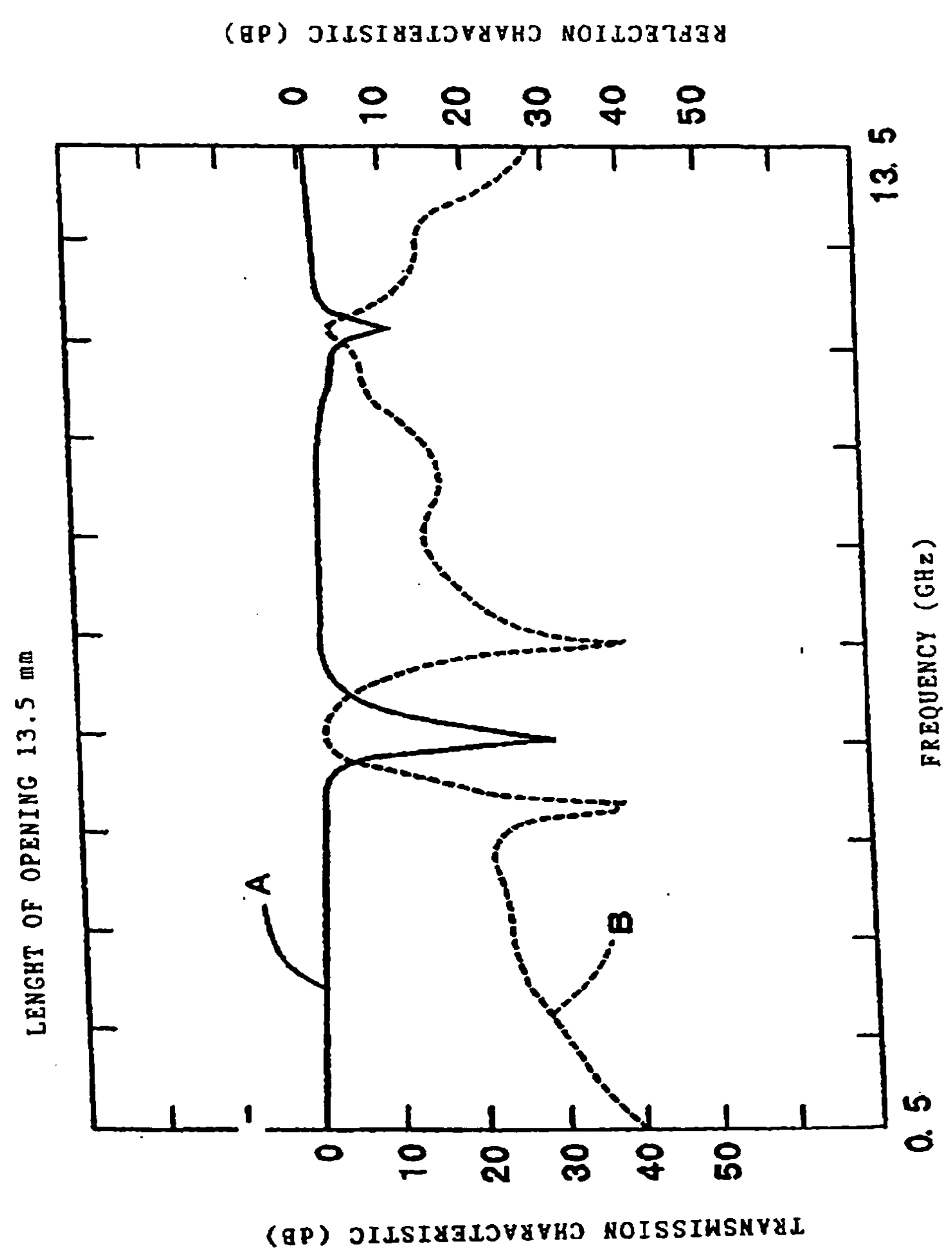

REFLECTION CHARACTERISTIC (dB)
0 10 20 30 40 50
LENGHT OF OPENING 13.5 mm
A
B
0 10 20 30 40 50
TRANSMISSION CHARACTERISTIC (dB)
0.5
13.5
FREQUENCY (GHz)

Fig. 9

Fig. 10A

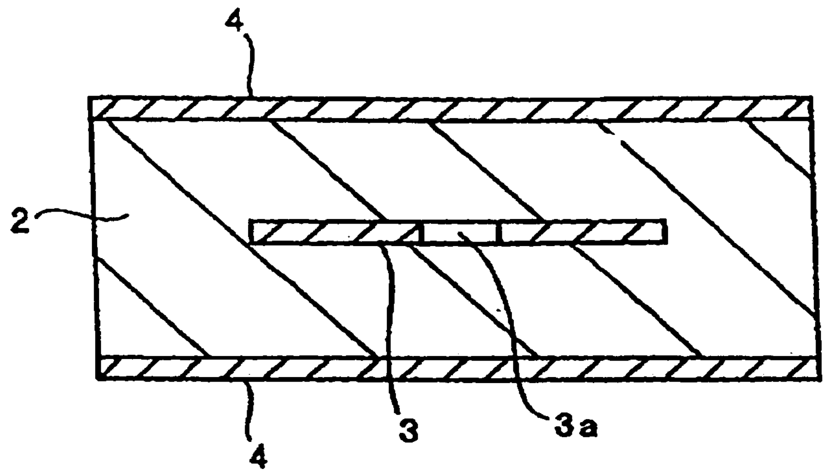
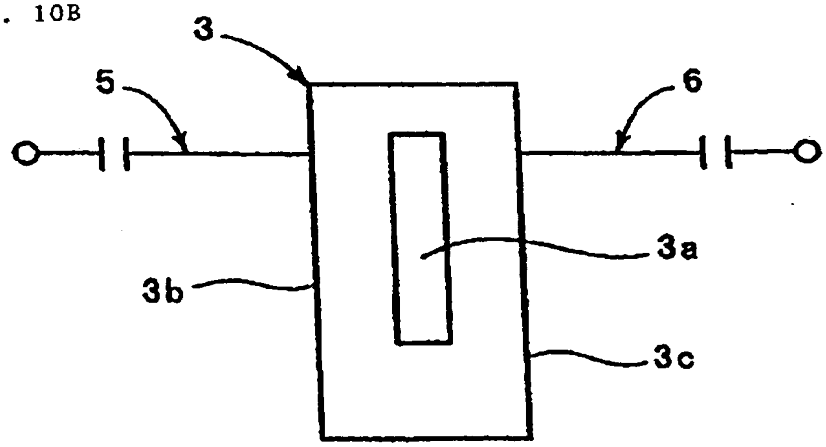



Fig. 10B



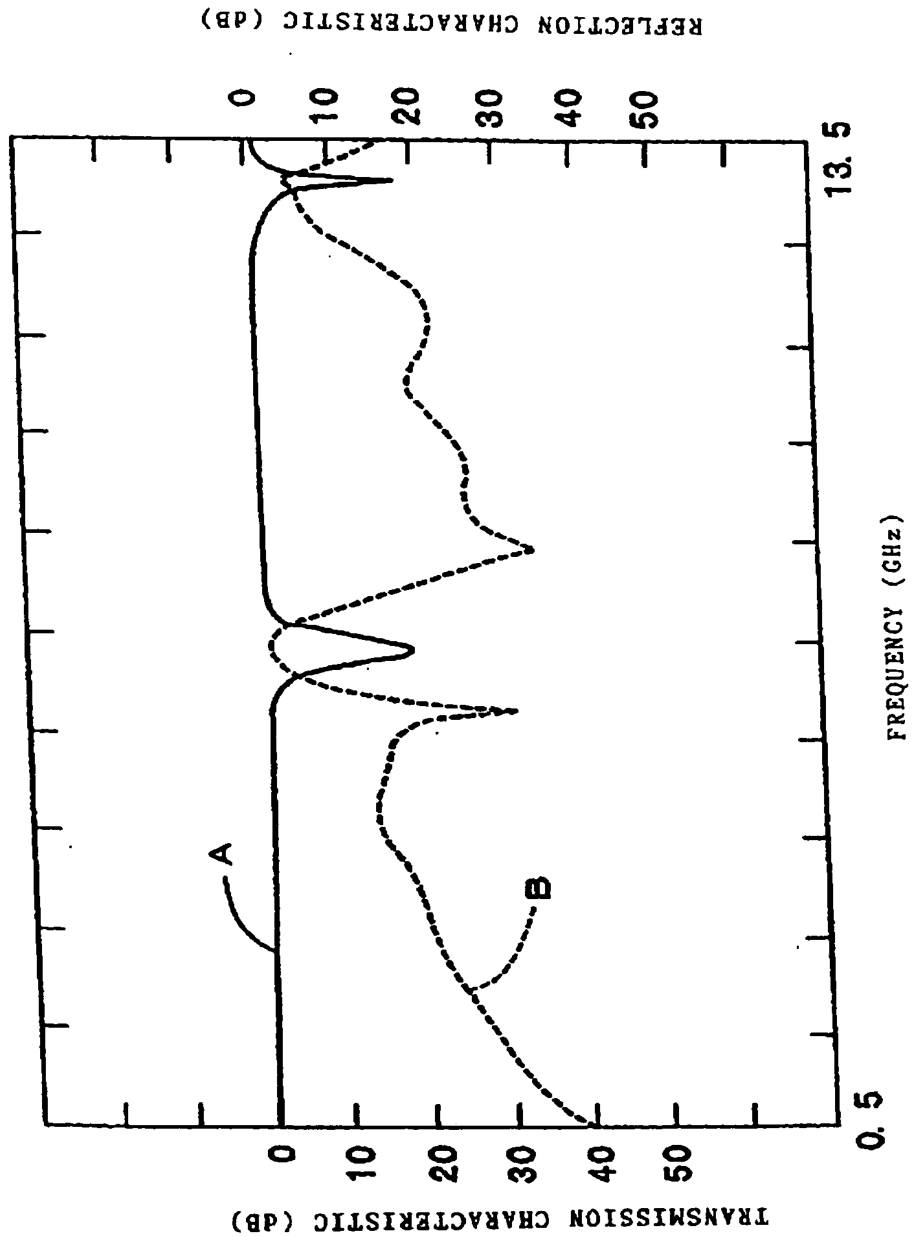
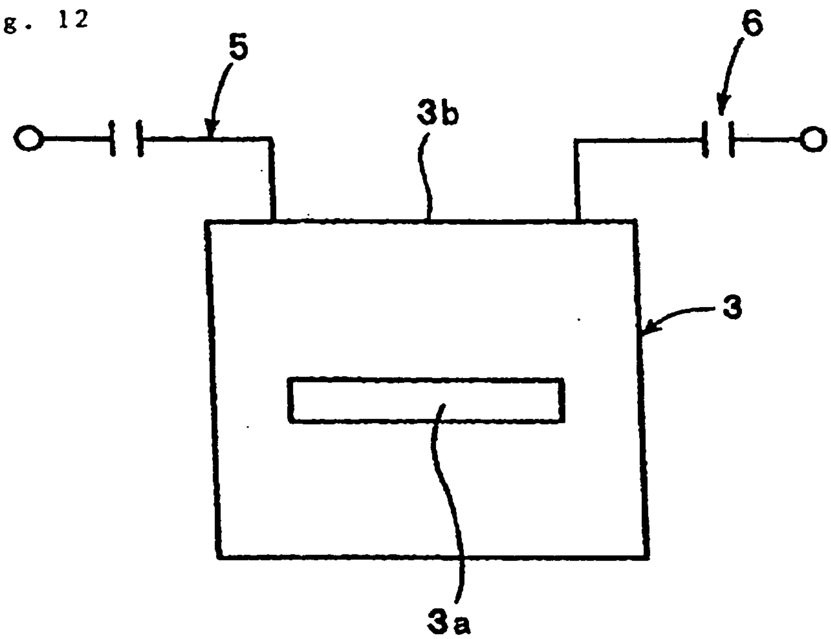

REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
A
B
0.5
13.5
FREQUENCY (GHz)
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig. 11

Fig. 12



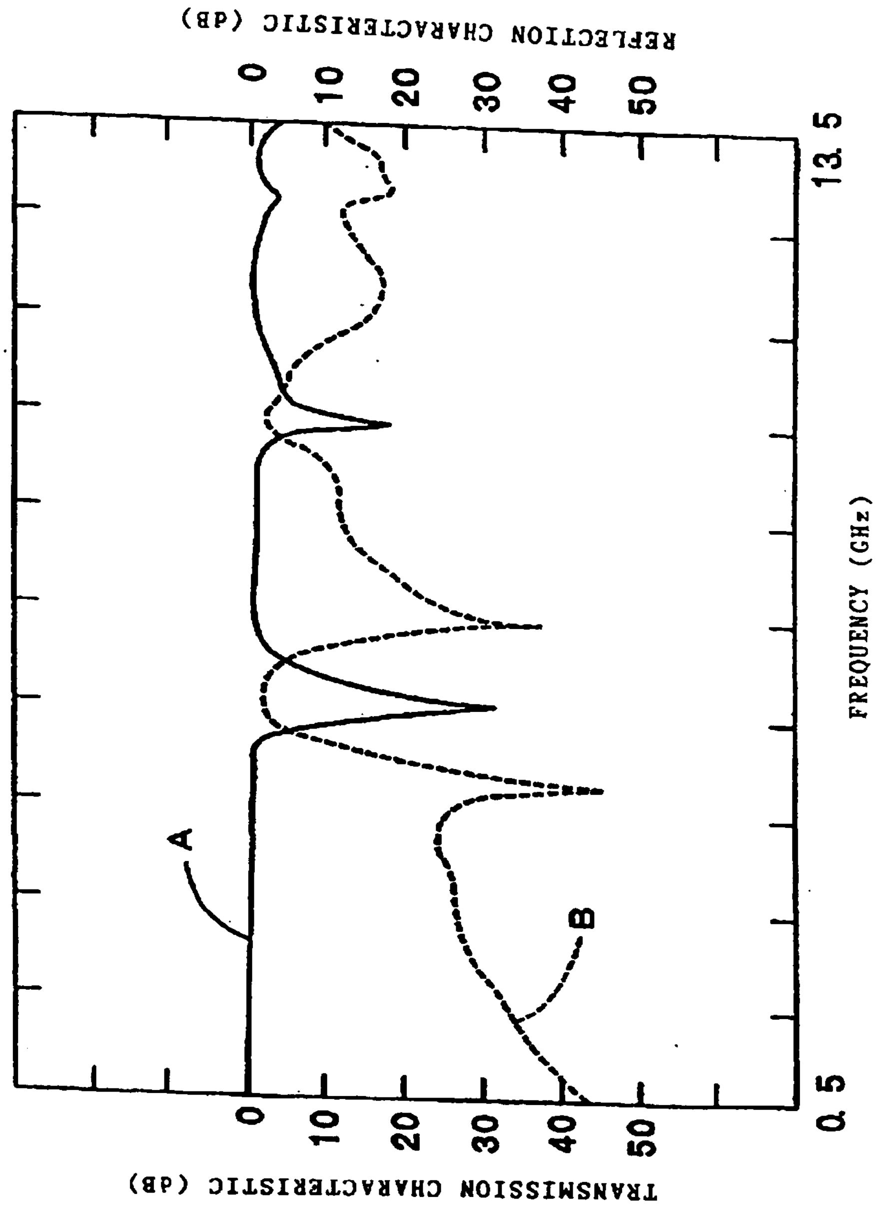

REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
A
B
0.5
13.5
FREQUENCY (GHz)
TRANSMISSION CHARACTERISTIC (dB)

Fig. 13

Fig. 14

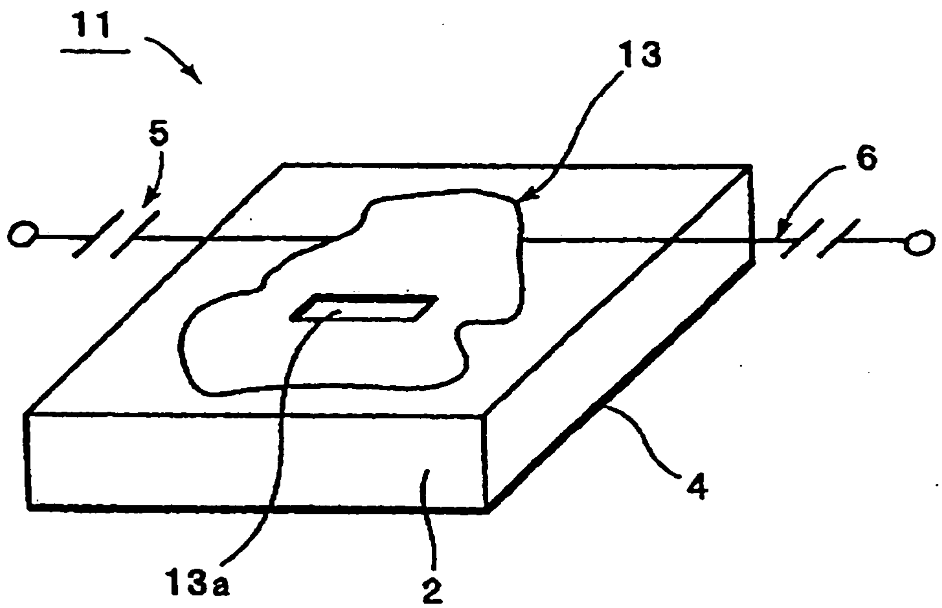
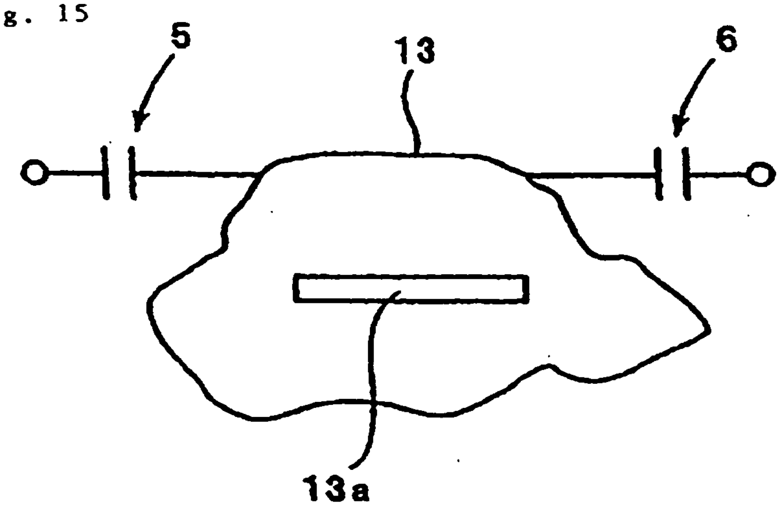



Fig. 15



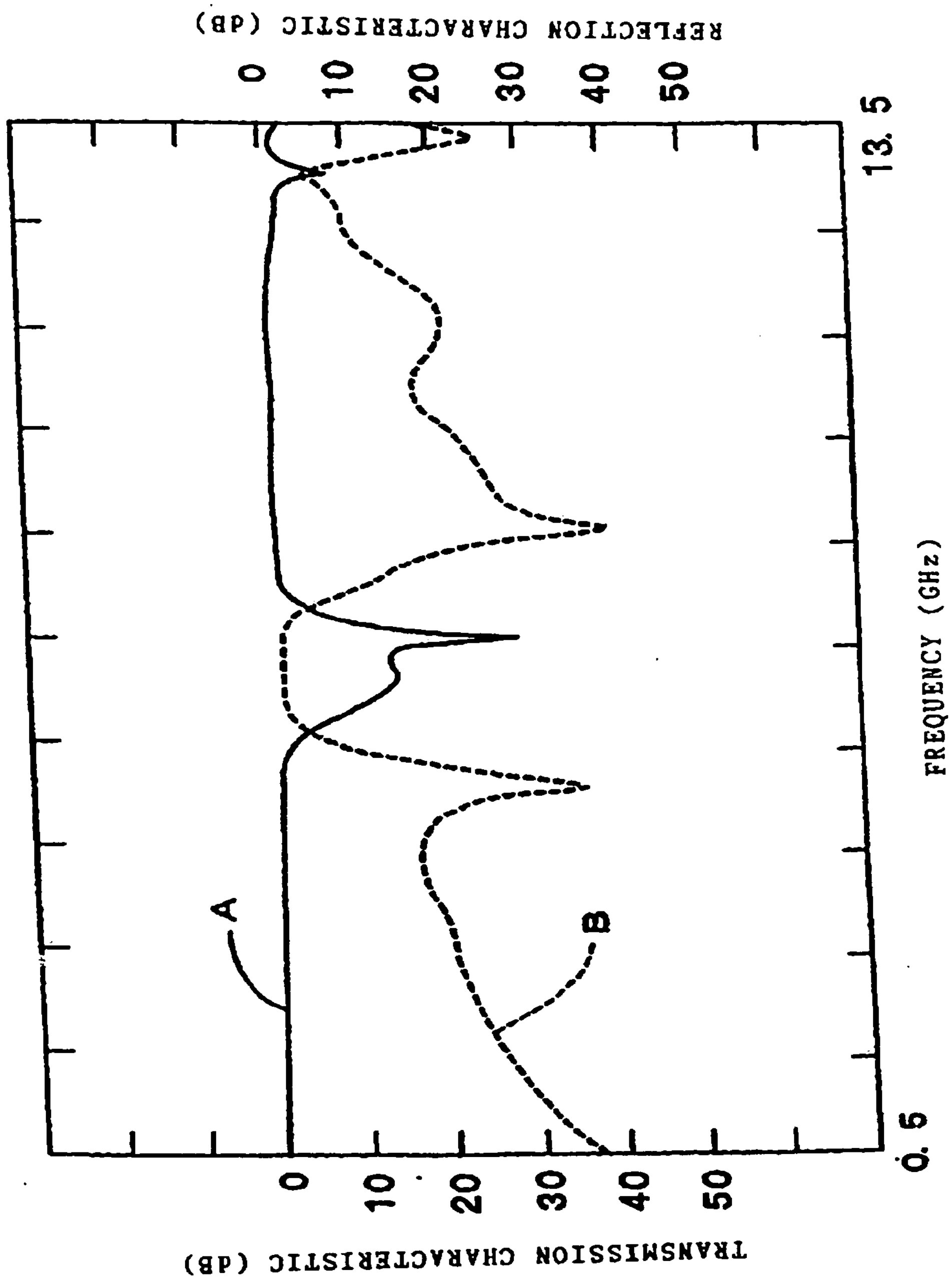
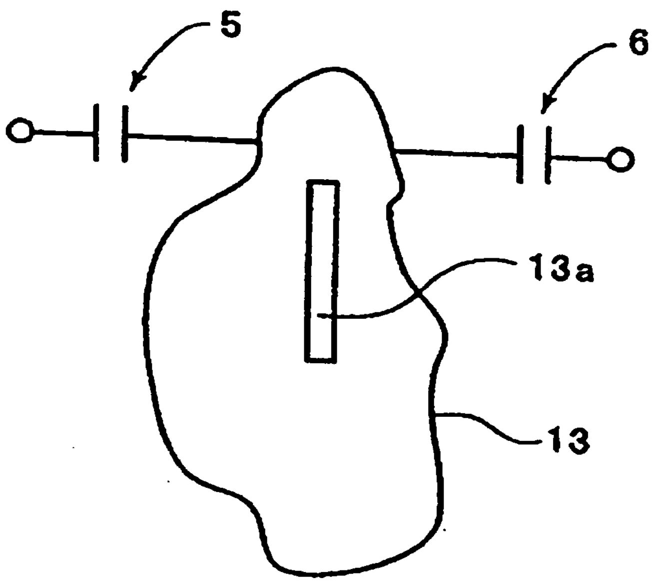

REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
13.5
A
B
FREQUENCY (GHz)
0.5
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig.16

Fig. 17



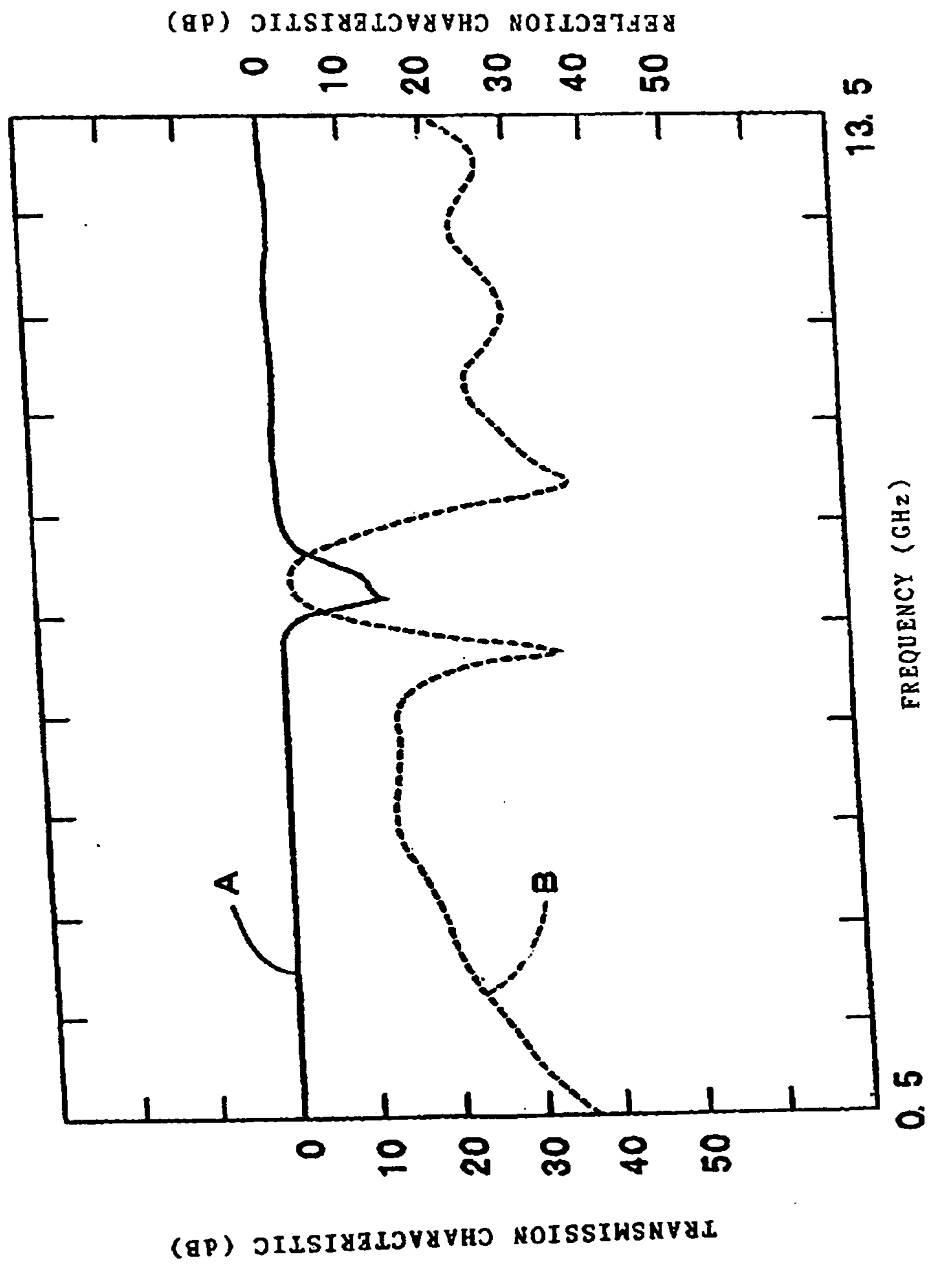
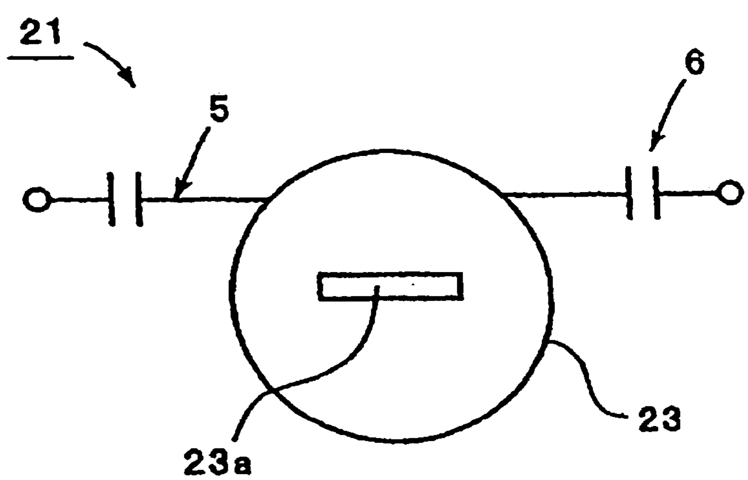
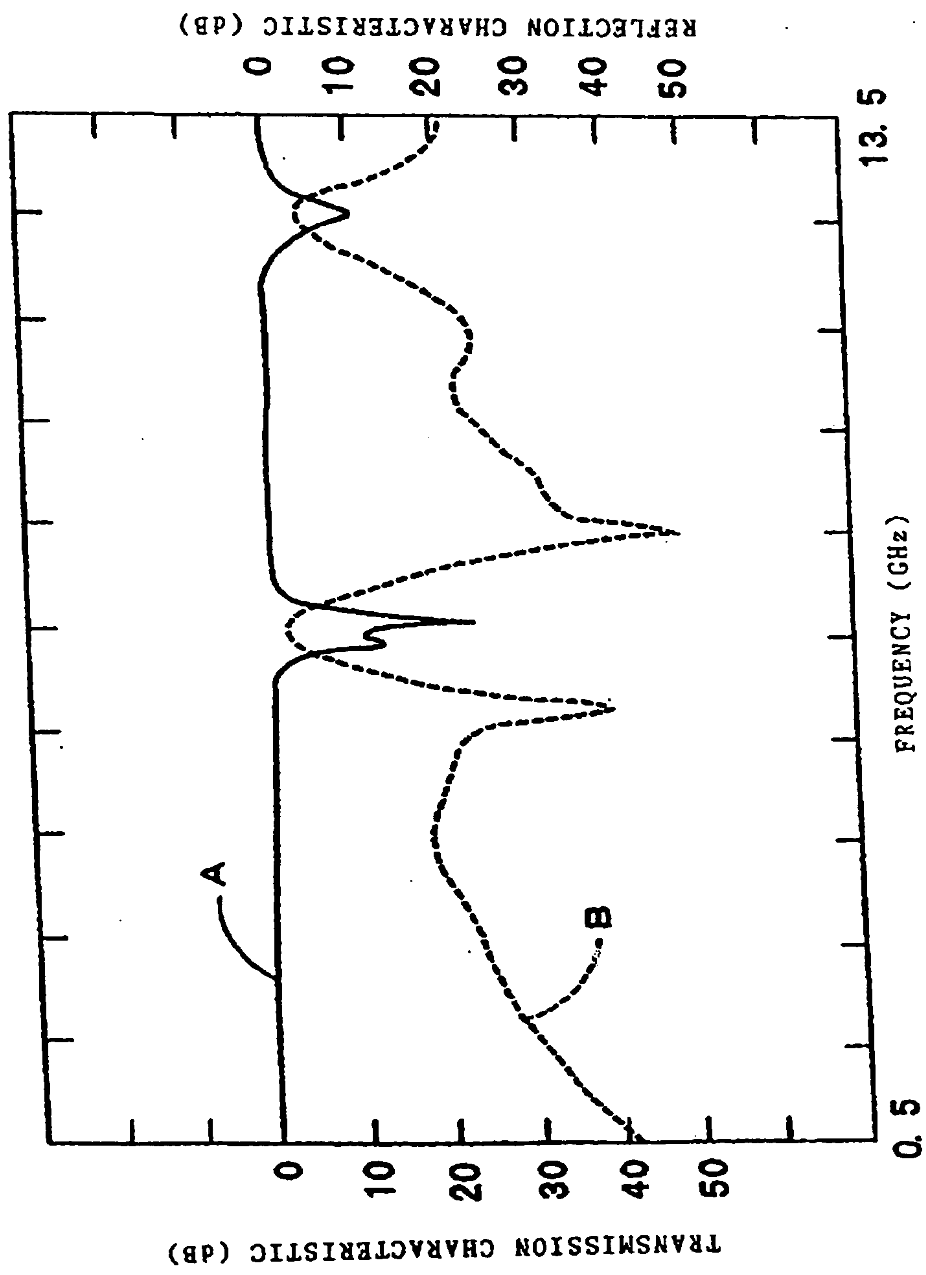

REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
13.5
0.5
FREQUENCY (GHz)
A
B
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig. 18

Fig. 19

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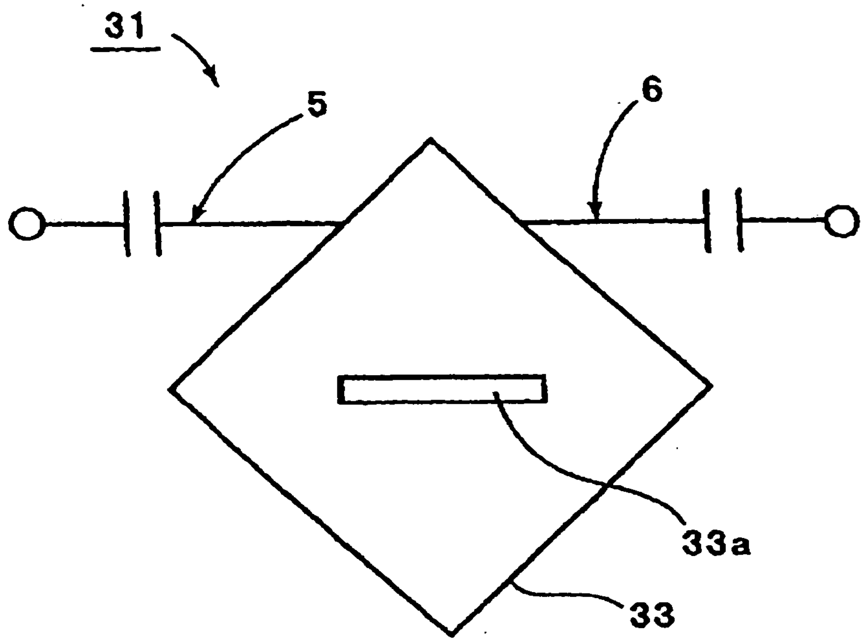
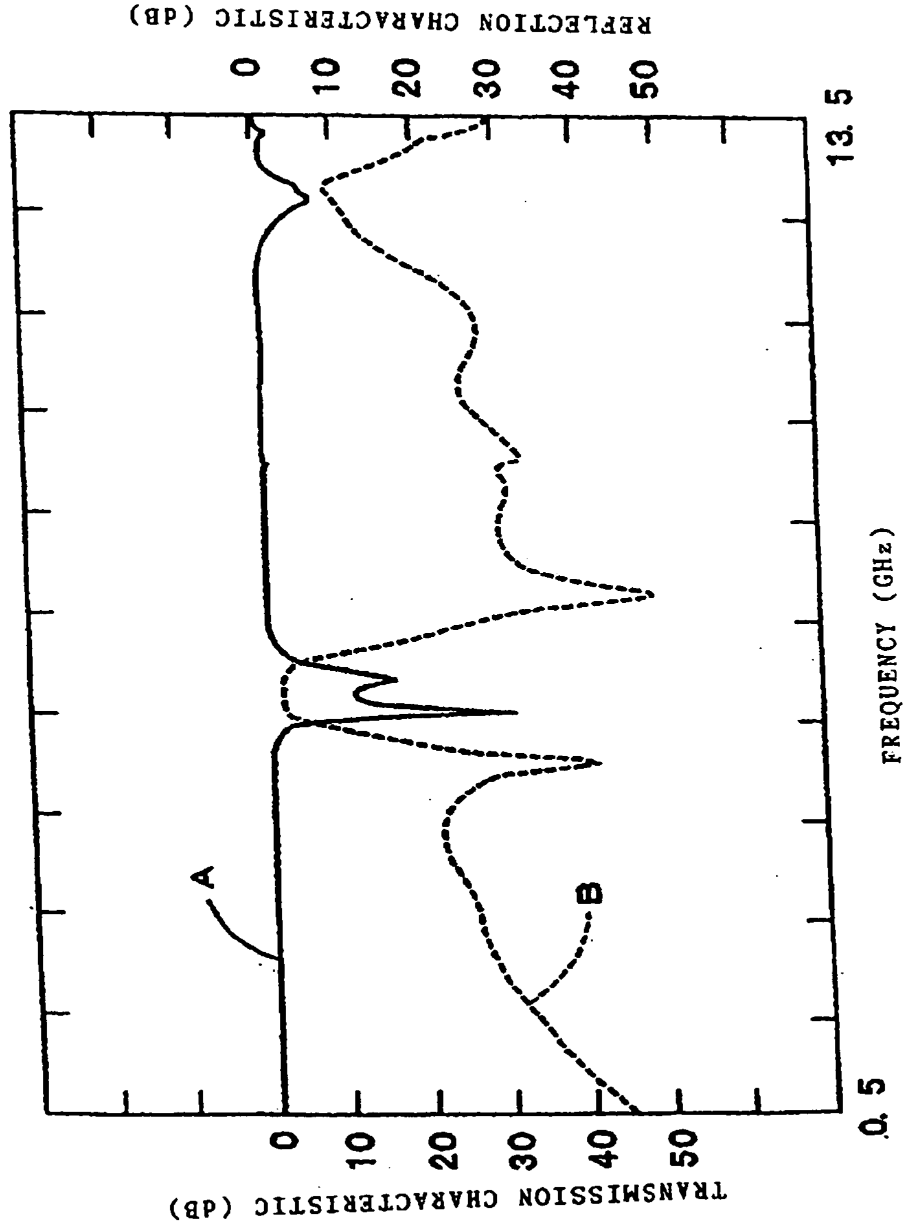
0 10 20 30 40 50
TRANSMISSION CHARACTERISTIC (dB)
0 10 20 30 40 50
FREQUENCY (GHz)
0.5
13.5
A
B

Fig. 20

Fig. 21

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TRANSMISSION CHARACTERISTIC (dB)
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FREQUENCY (GHz)
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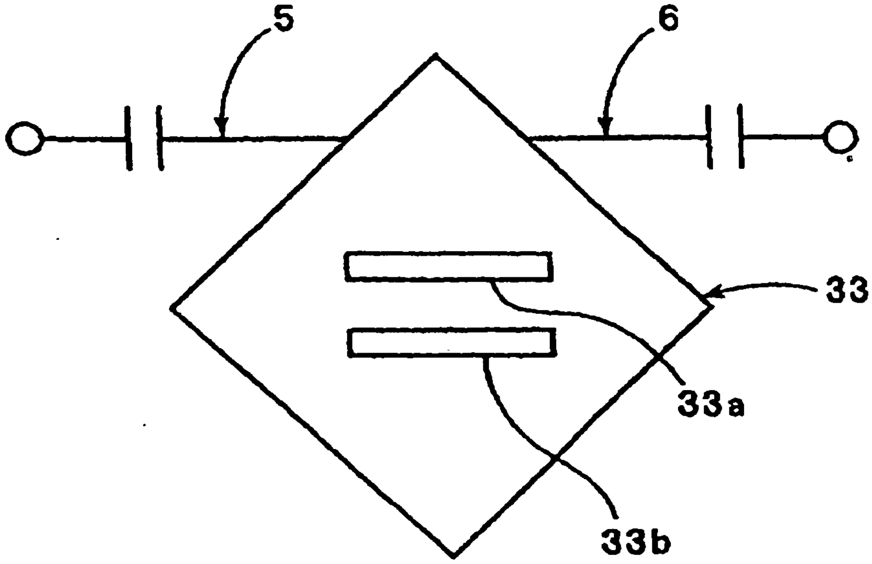
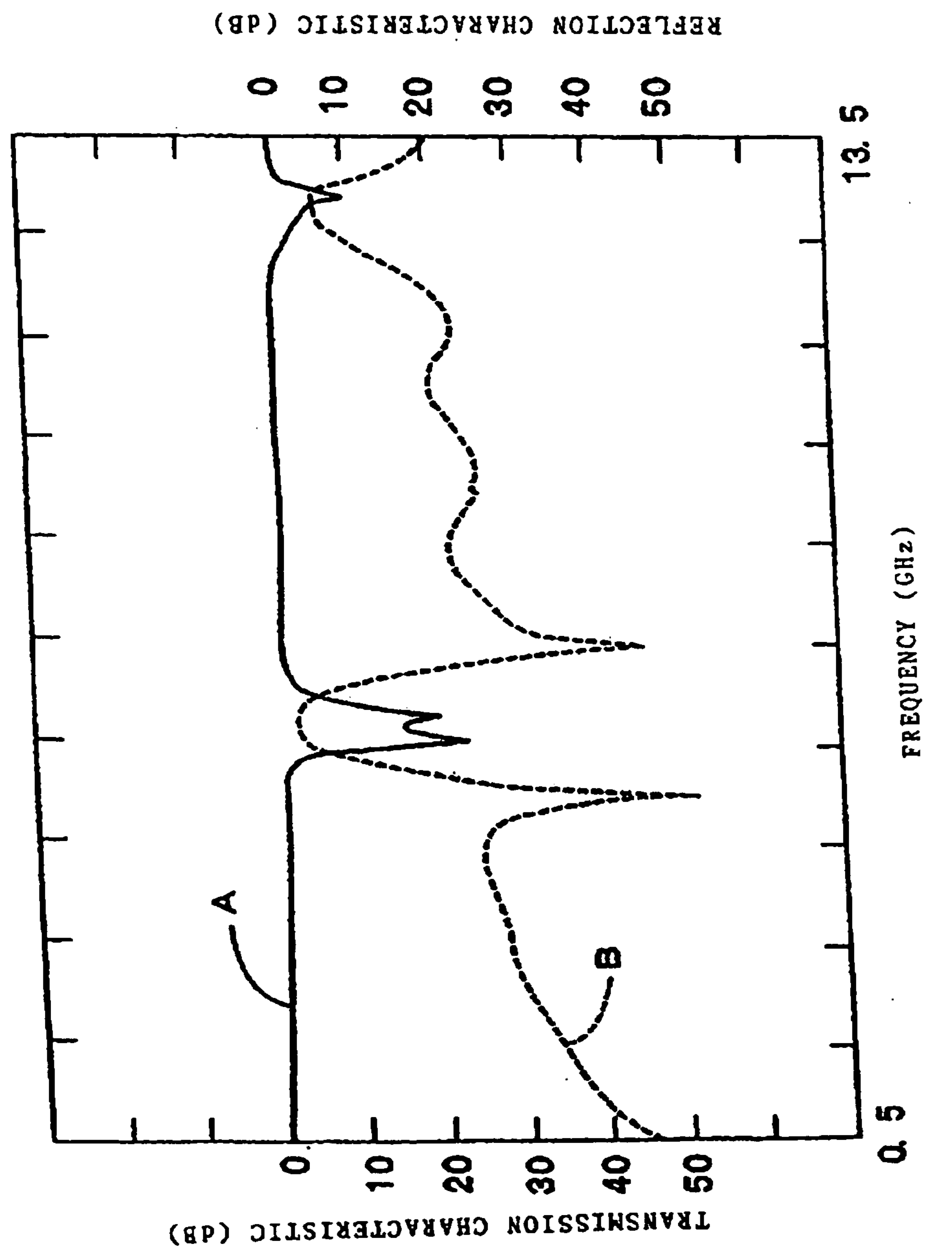
13.5
A
B

Fig.22

Fig. 23

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30
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13.5
A
B
FREQUENCY (GHz)
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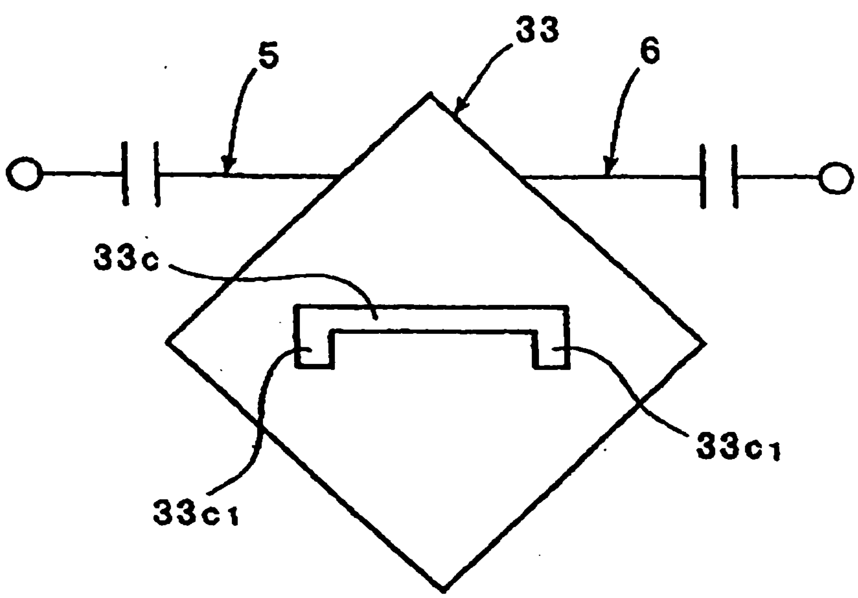
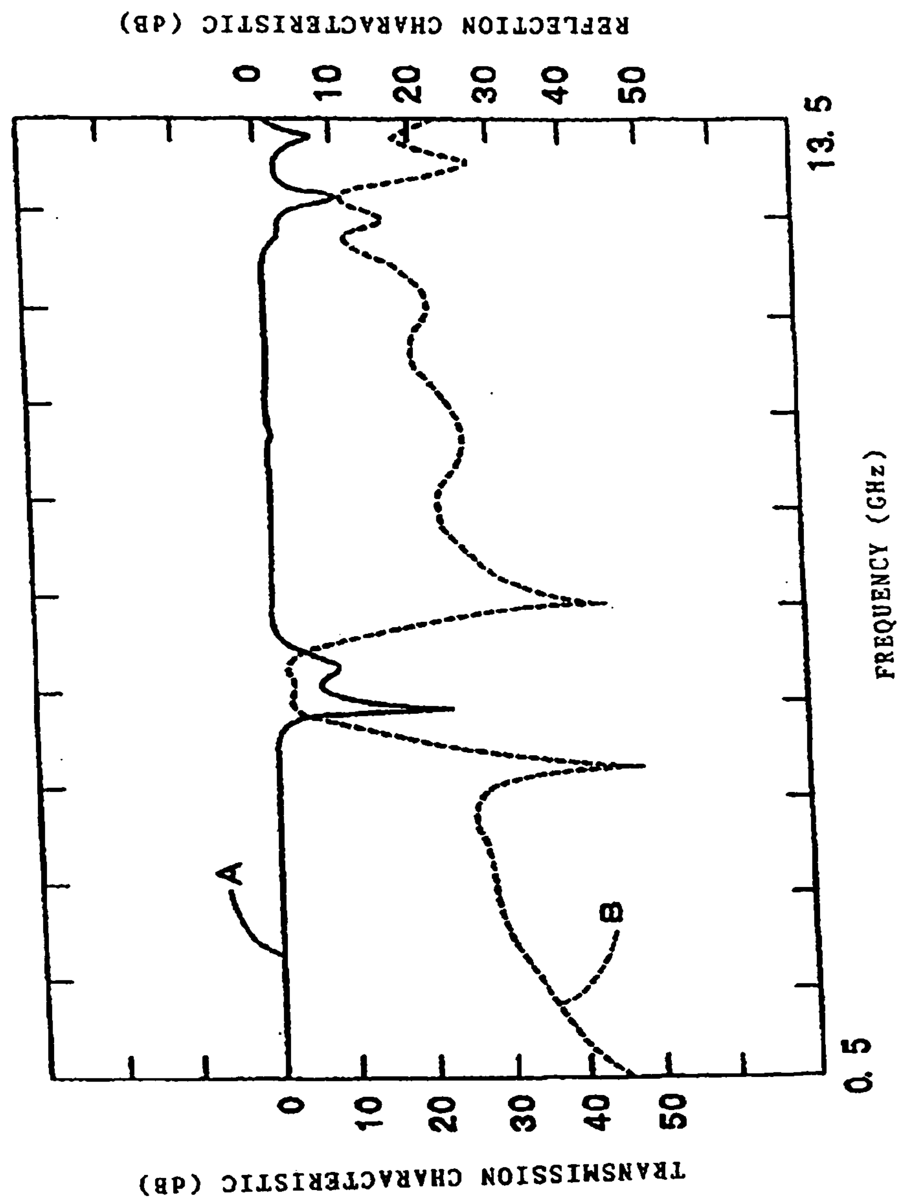
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig. 24

Fig. 25

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13.5
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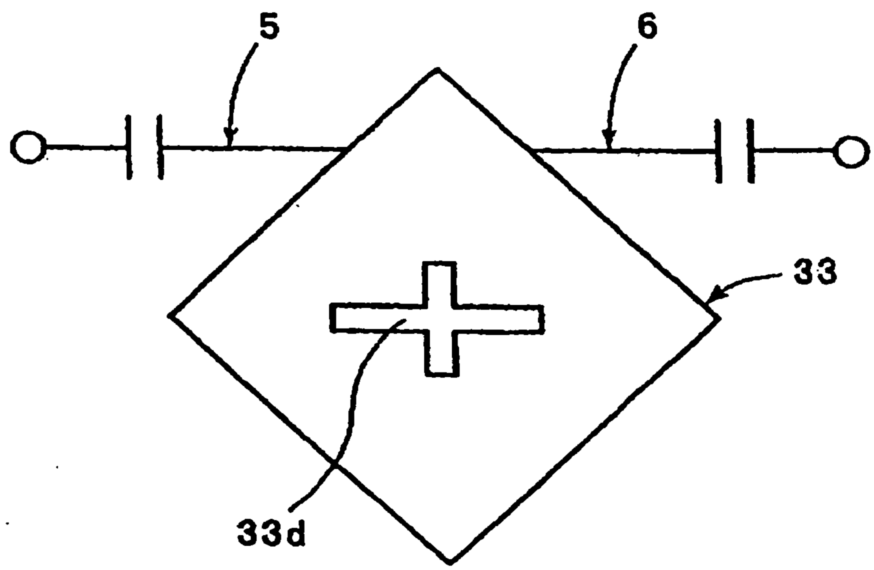
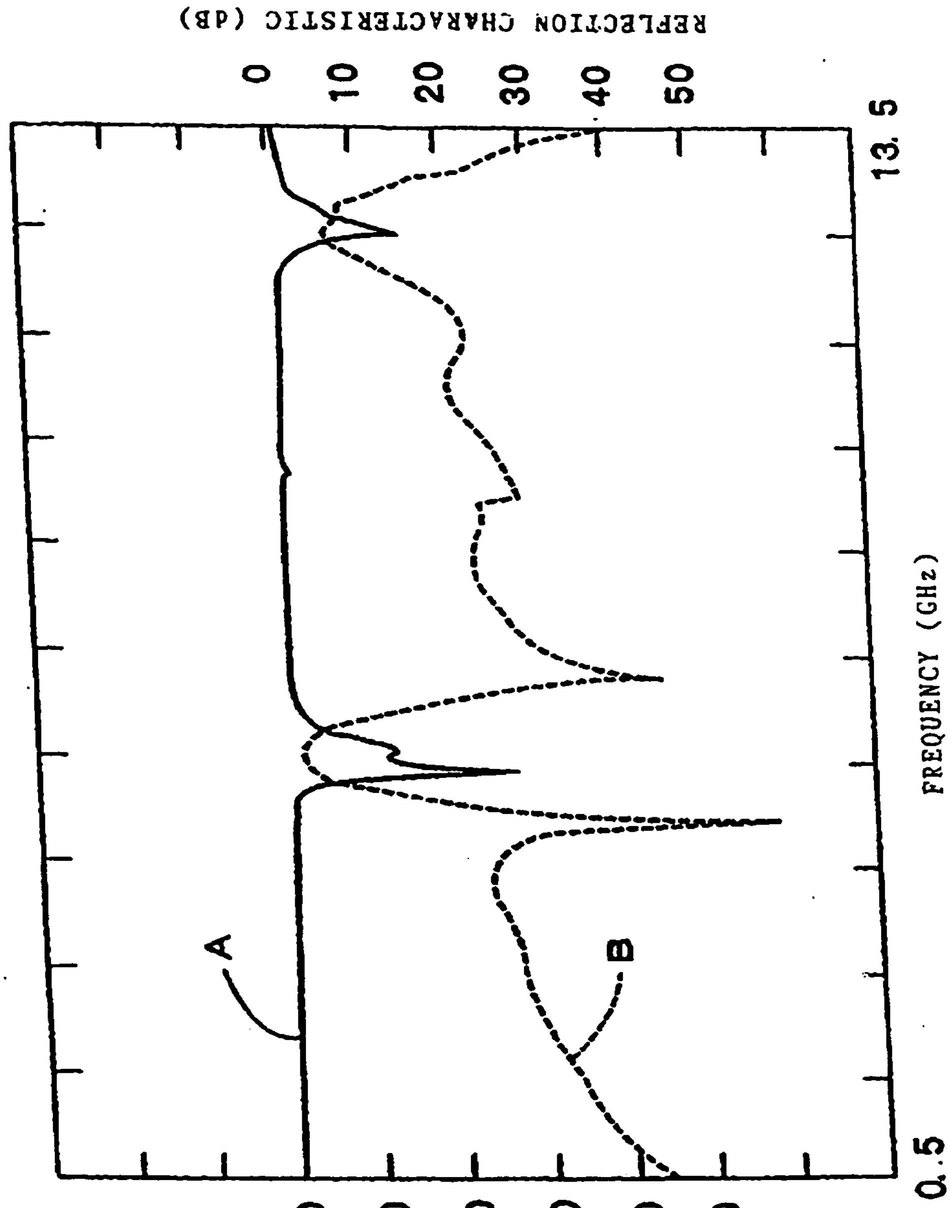
FREQUENCY (GHz)
A
B
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig. 26

Fig. 27

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50
TRANSMISSION CHARACTERISTIC (dB)
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10
20
30
40
50
FREQUENCY (GHz)
0.5
13.5
A
B

Fig. 28

Fig. 29

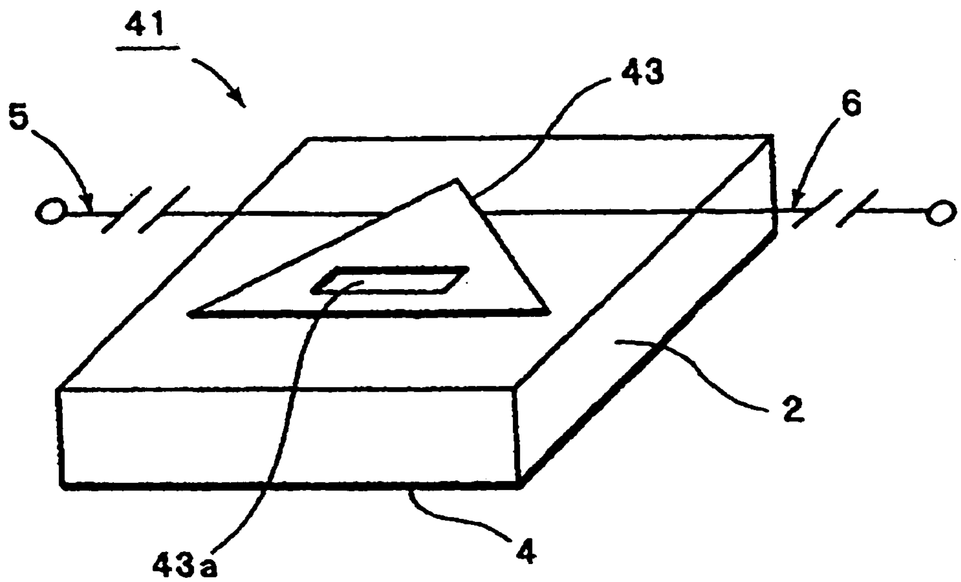
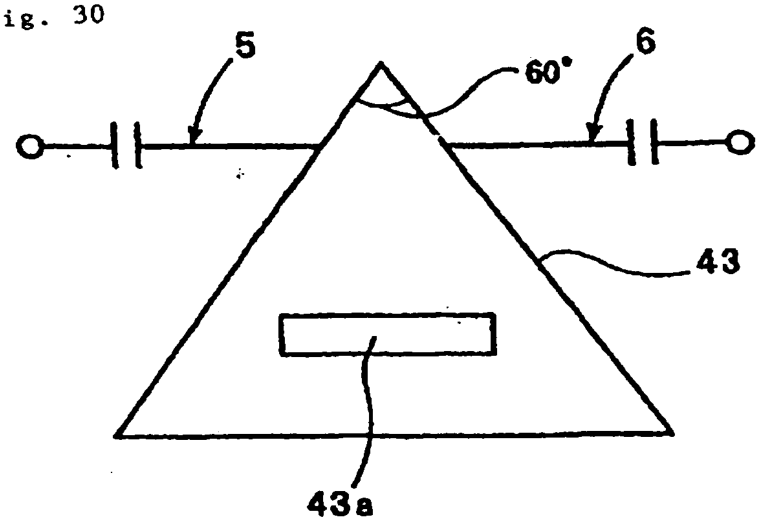
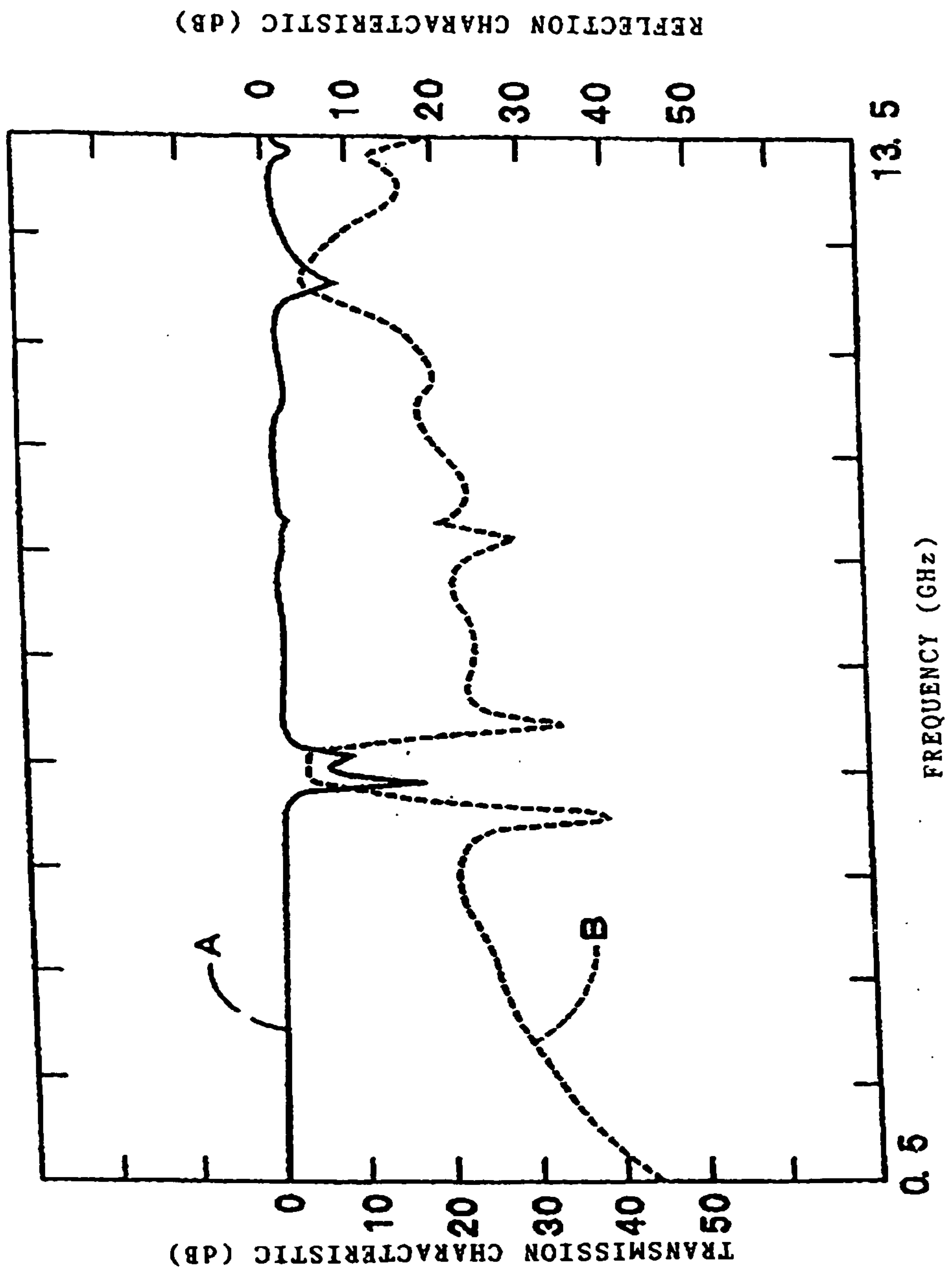



Fig. 30

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TRANSMISSION CHARACTERISTIC (dB)
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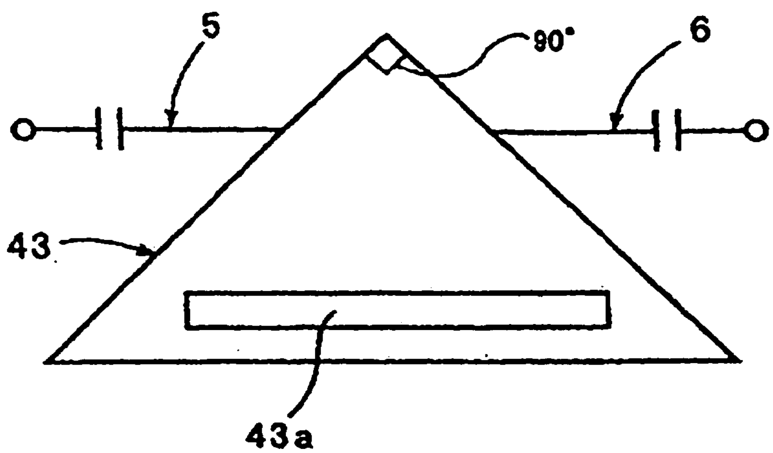
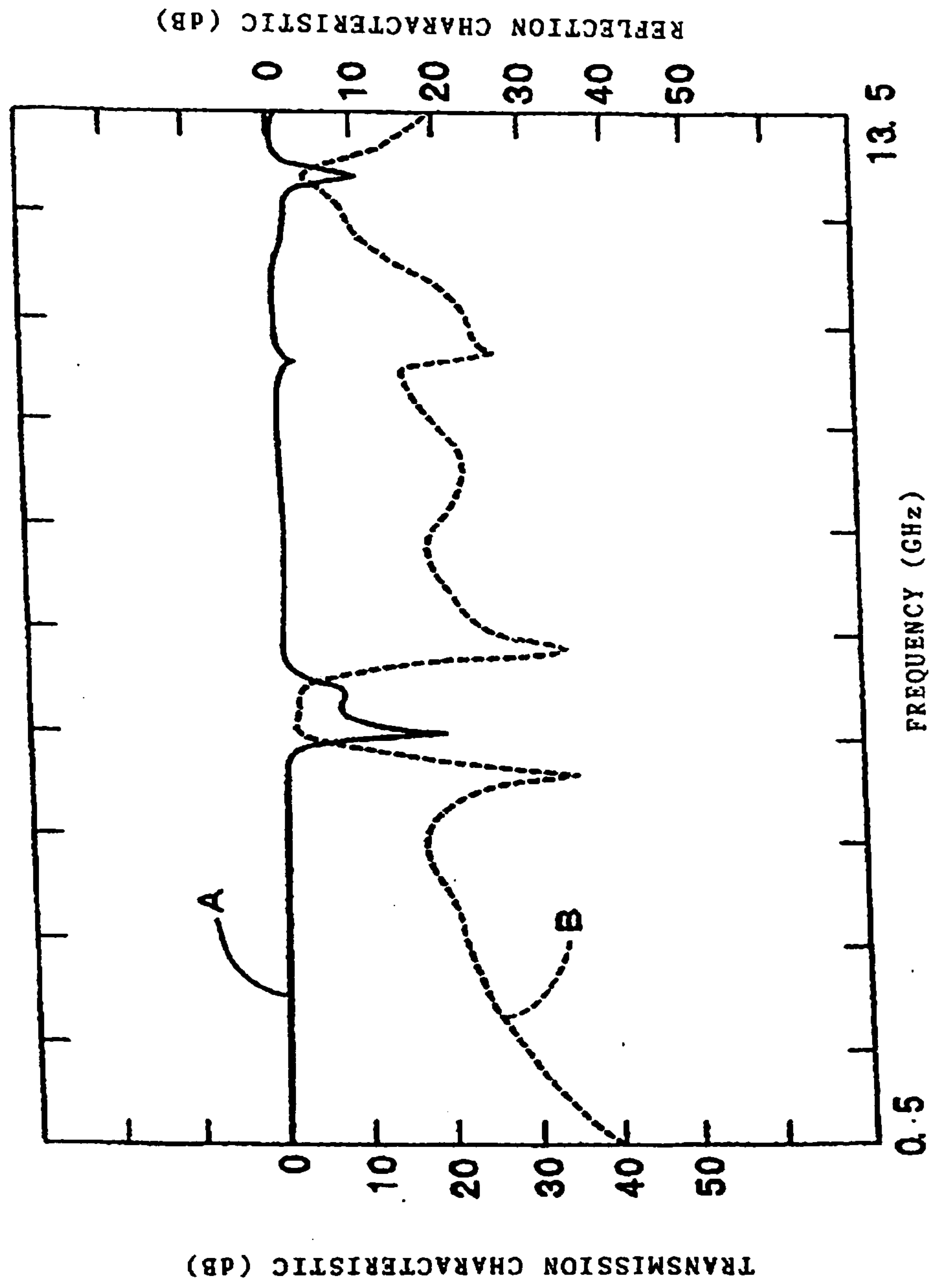
10
20
30
40
50
FREQUENCY (GHz)
0.5
13.5
A
B

Fig. 31

Fig. 32

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30
40
50
13.5
FREQUENCY (GHz)
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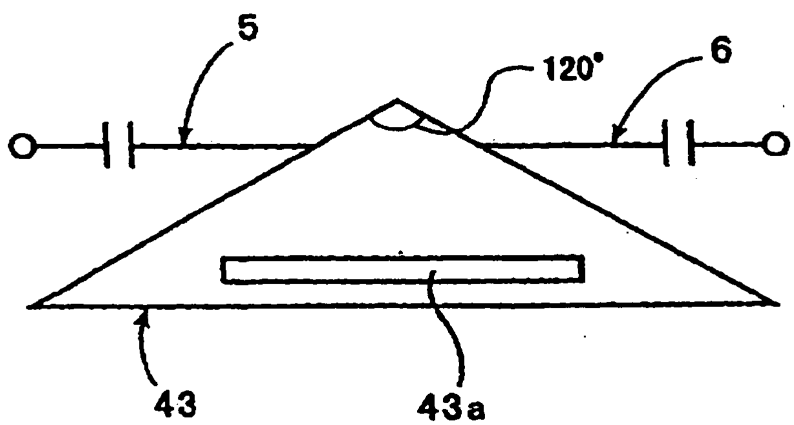
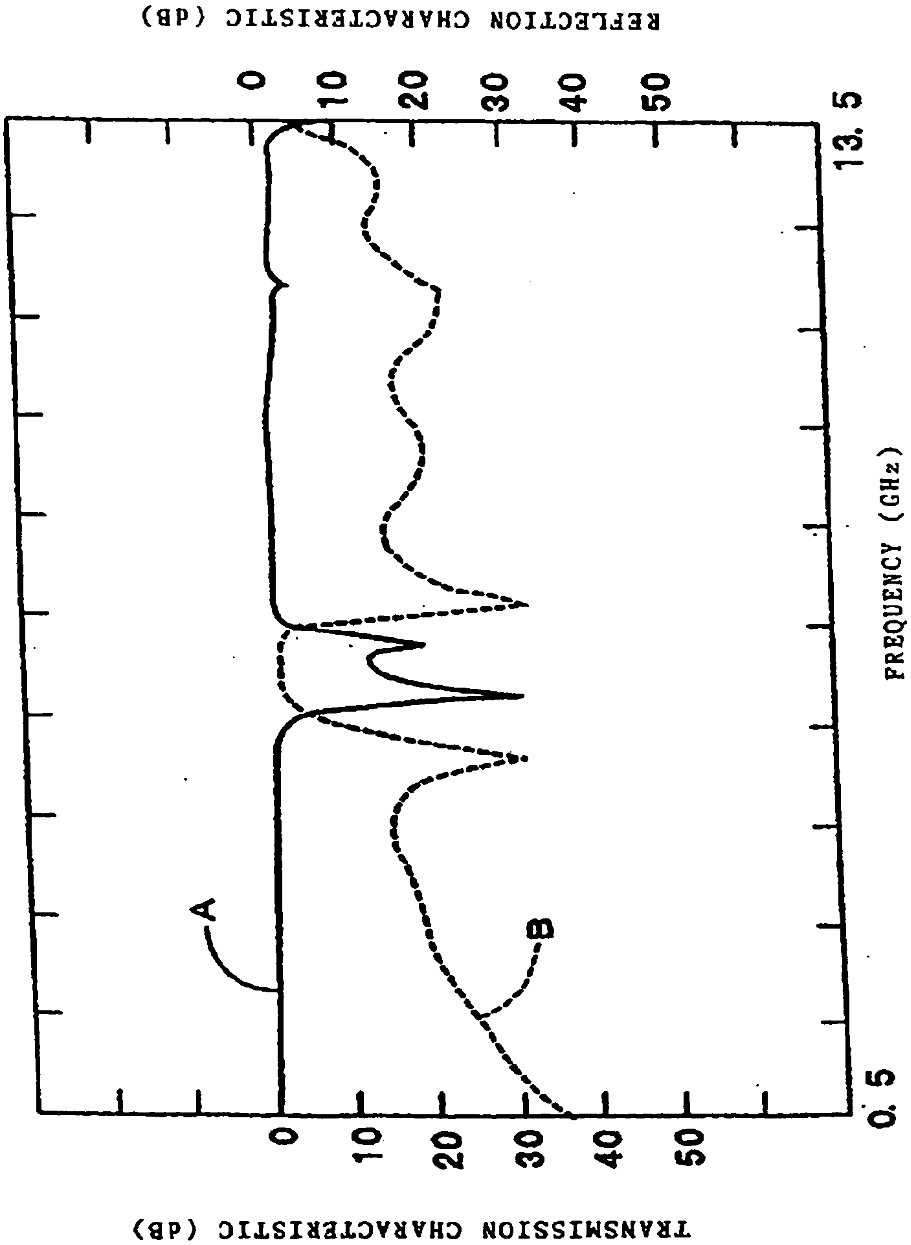
A
B
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig. 33

Fig. 34

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20
30
40
50
13.5
FREQUENCY (GHz)
0.5
A
B
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig. 35

Fig. 36

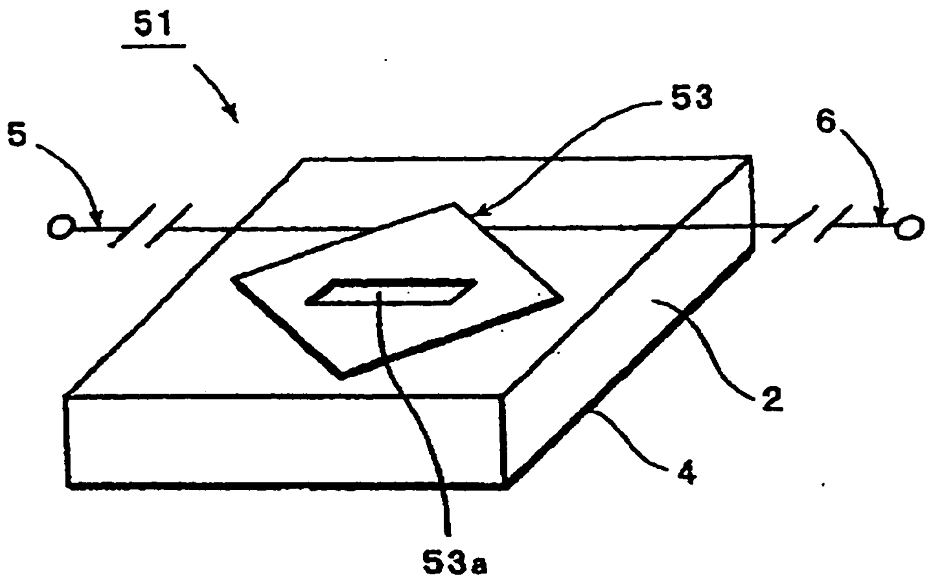
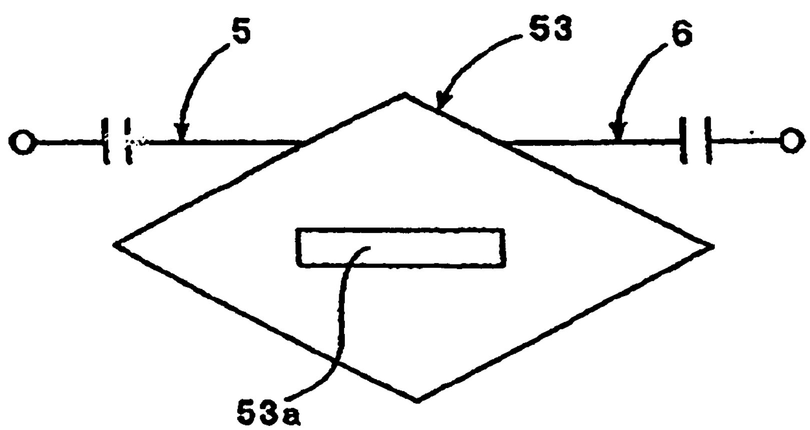
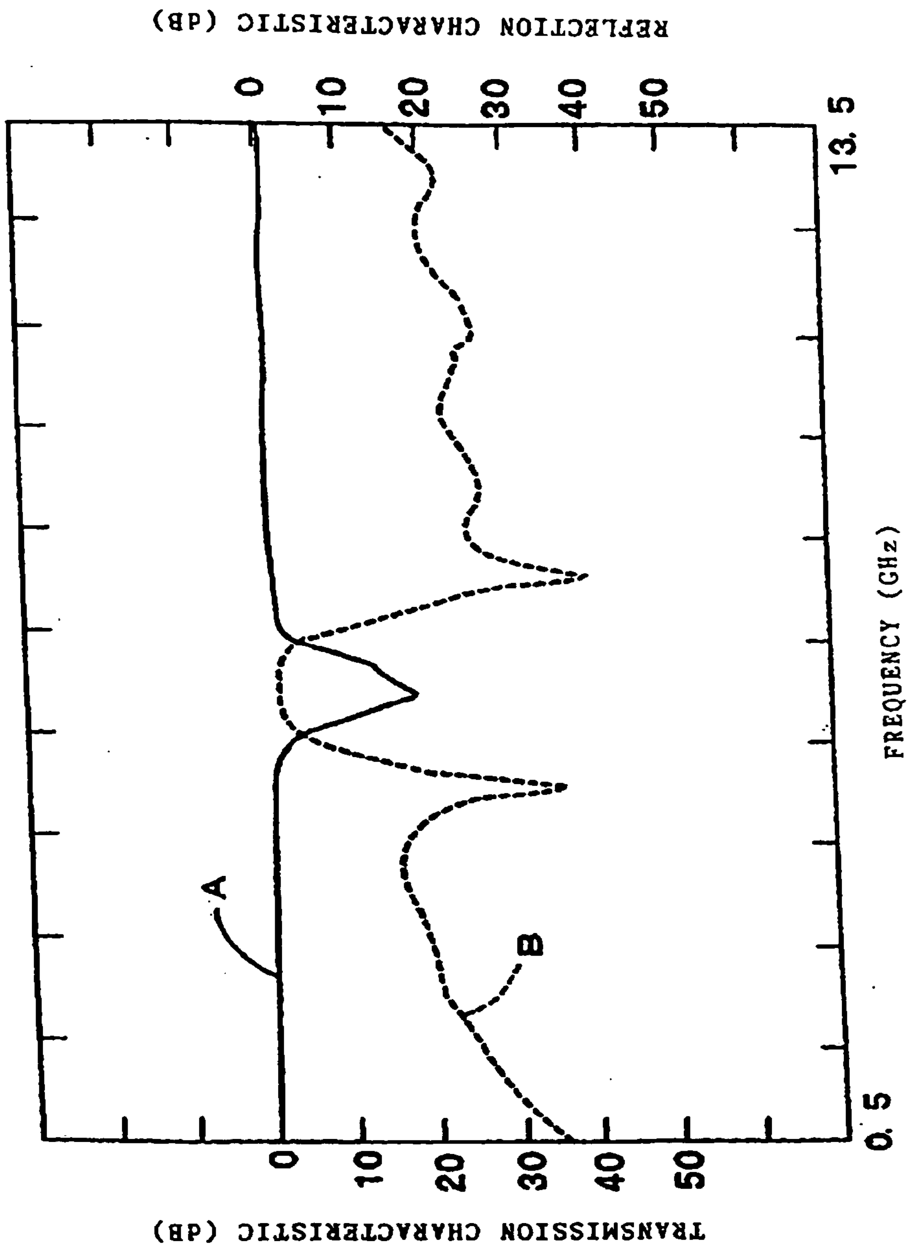



Fig. 37

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13.5
FREQUENCY (GHz)
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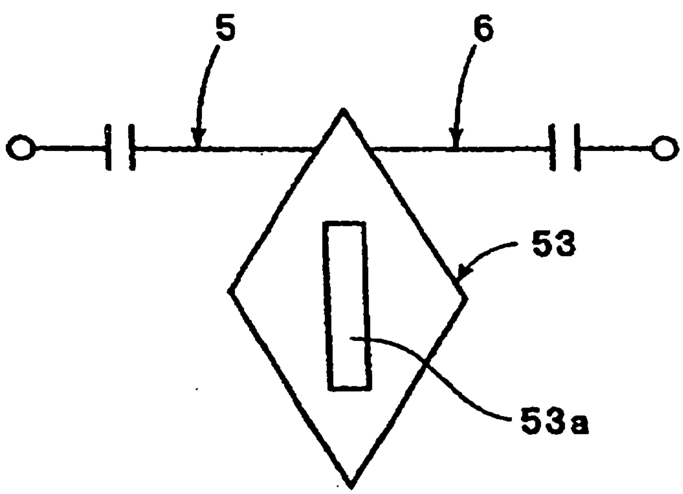
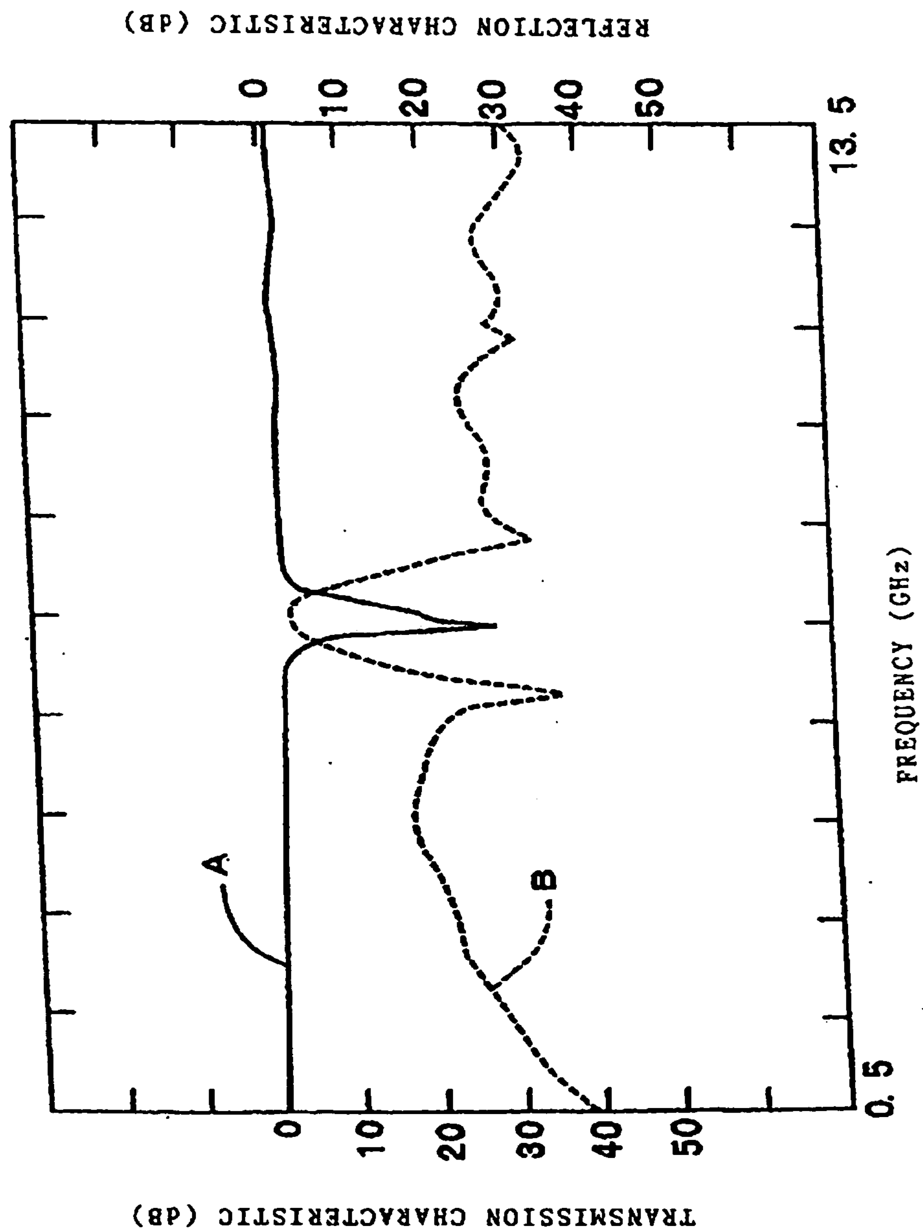
A
B
0
10
20
30
40
50
TRANSMISSION CHARACTERISTIC (dB)

Fig. 38

Fig. 39

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13.5
0.5
FREQUENCY (GHz)
A
B
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40
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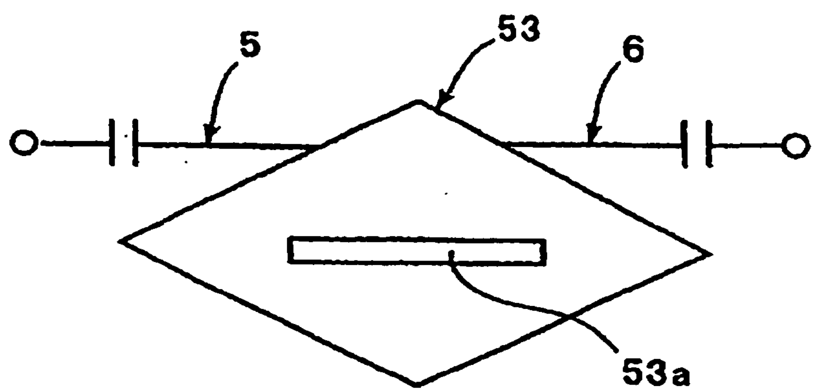
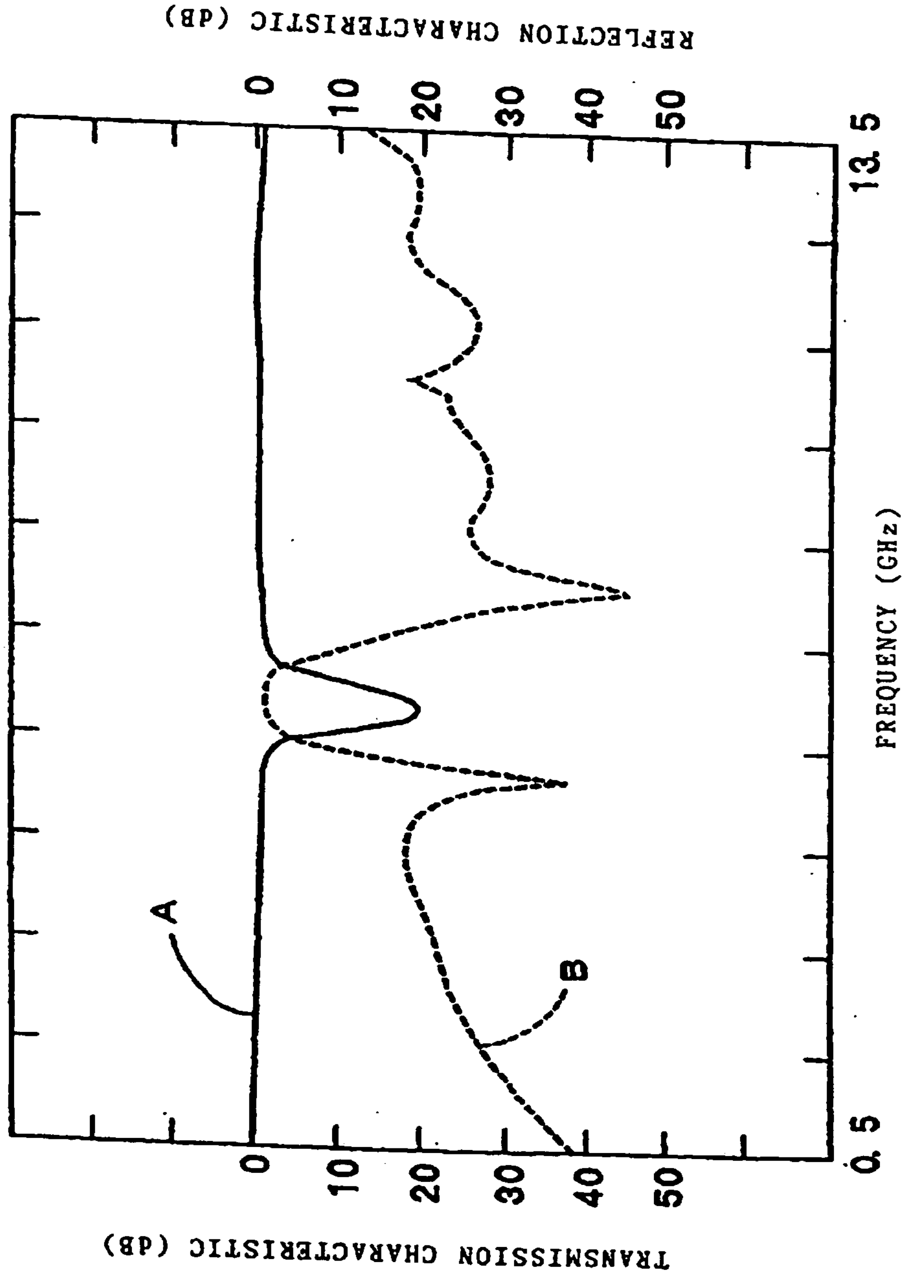
TRANSMISSION CHARACTERISTIC (dB)

Fig. 40

Fig. 41

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50
TRANSMISSION CHARACTERISTIC (dB)
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20
30
40
50
FREQUENCY (GHz)
0.5
13.5
A
B

Fig. 42

Fig. 43

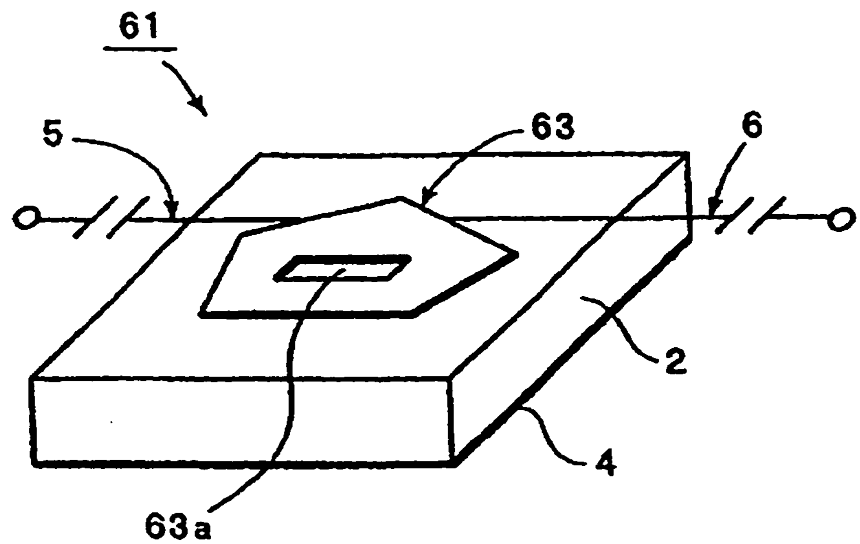
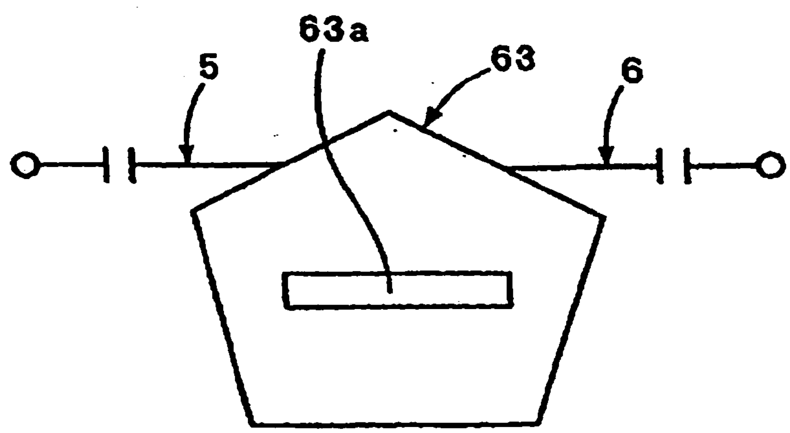
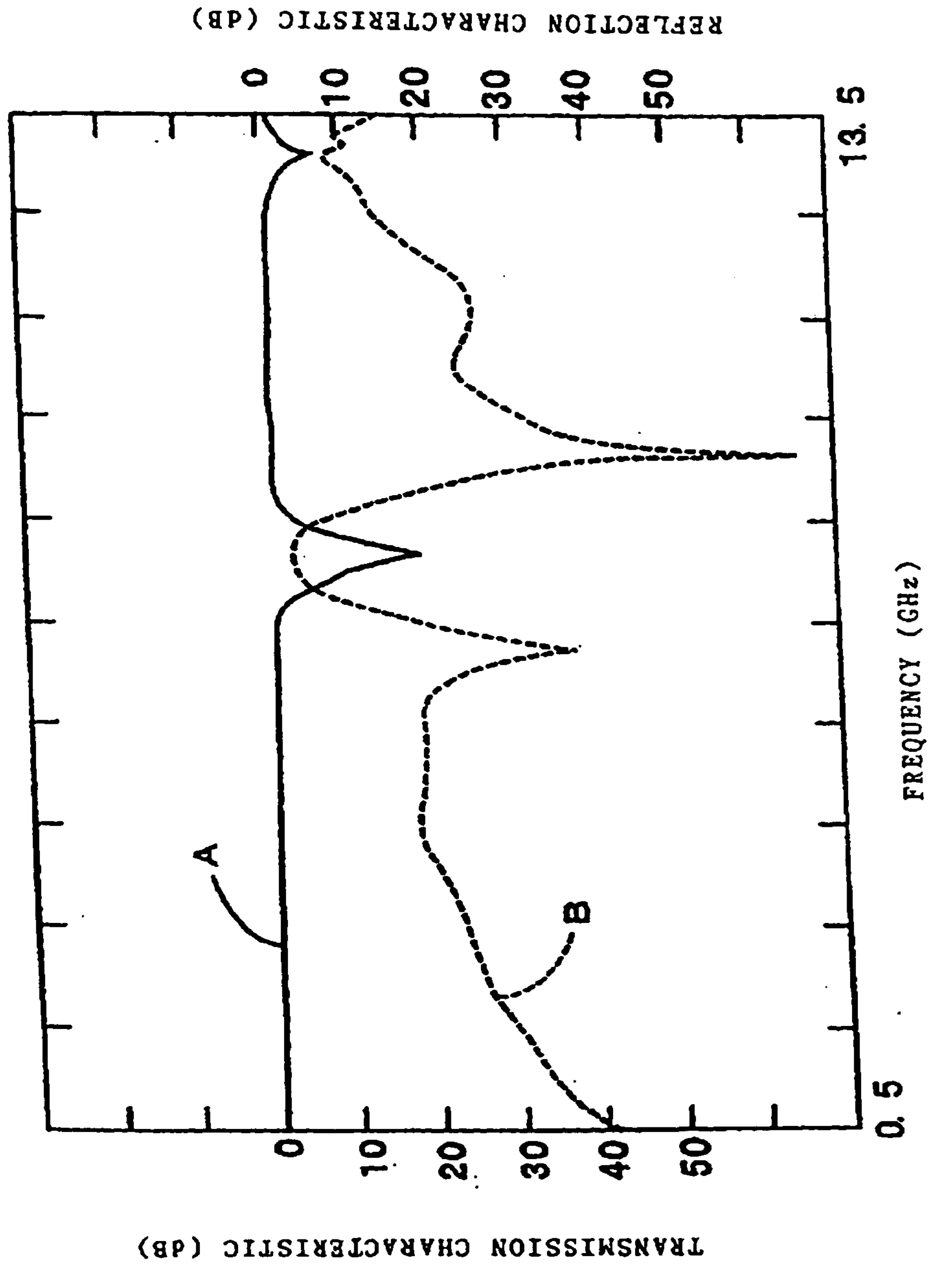



Fig. 44

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TRANSMISSION CHARACTERISTIC (dB)
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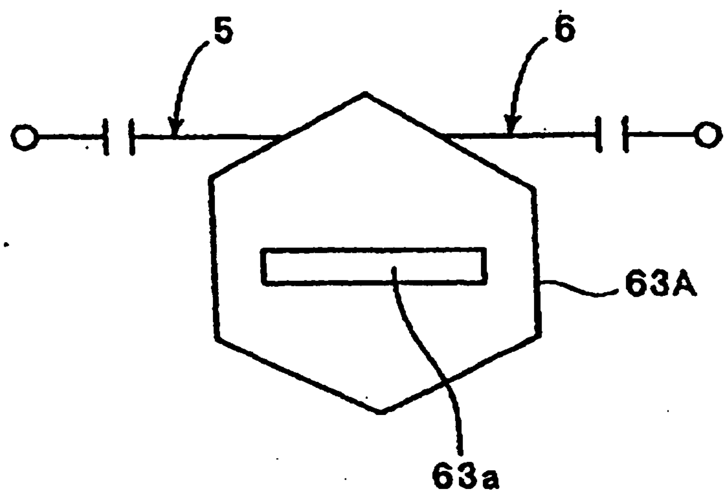
50
0.5
13.5
FREQUENCY (GHz)
A
B

Fig. 45

Fig. 46



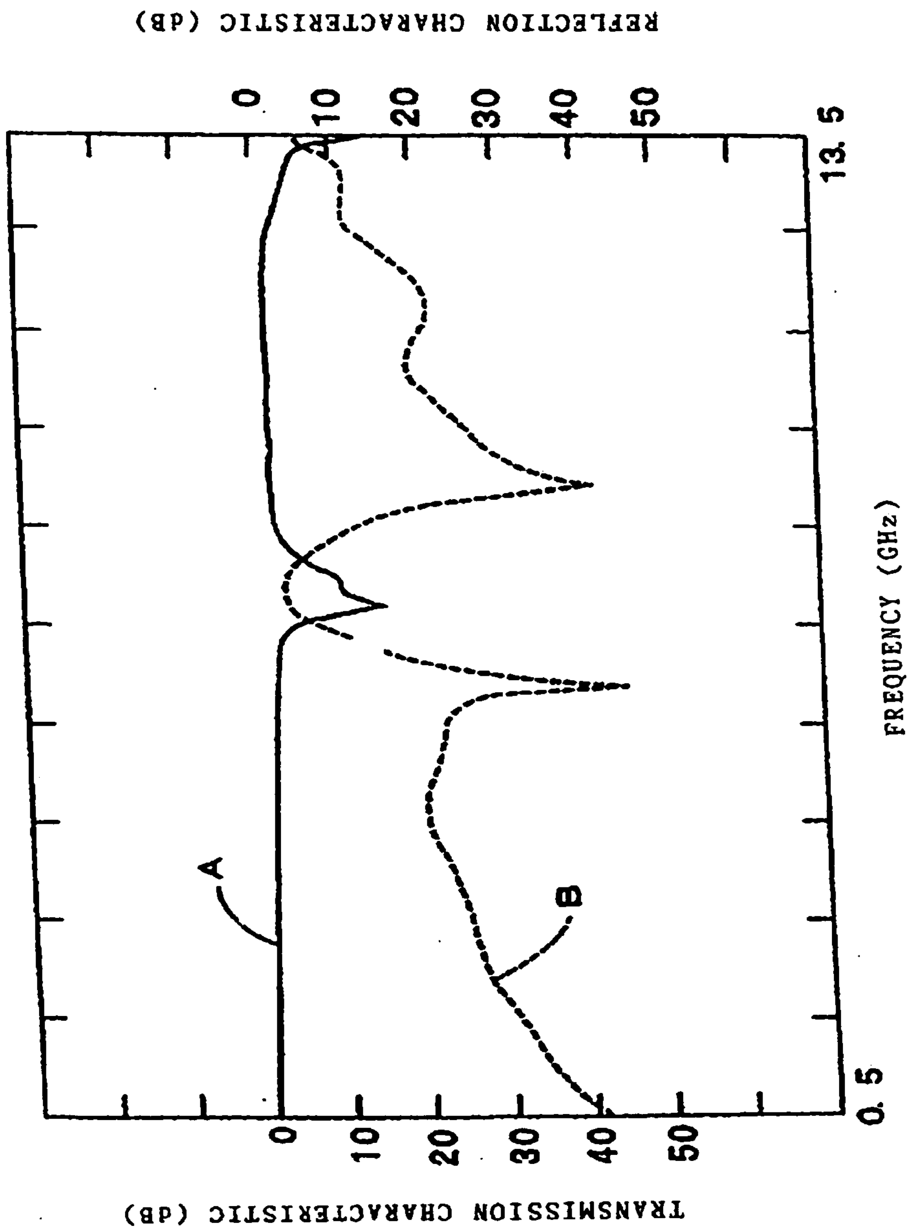

REFLECTION CHARACTERISTIC (dB)
0
10
20
30
40
50
A
B
FREQUENCY (GHz)
0.5
13.5
TRANSMISSION CHARACTERISTIC (dB)

Fig. 47

Fig. 48

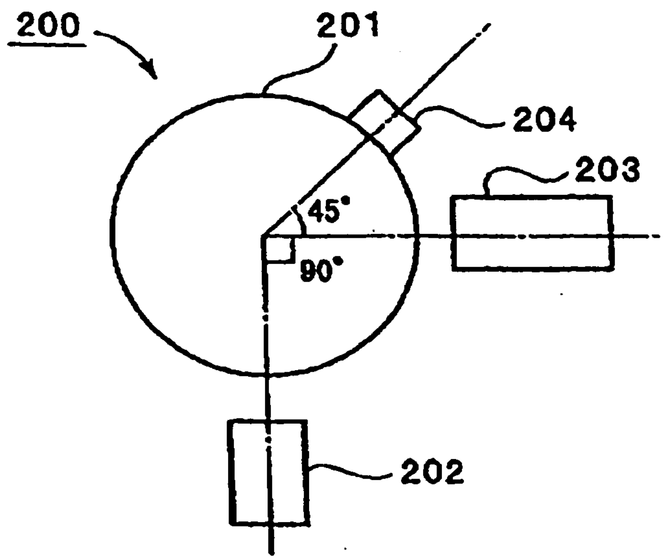



Fig. 49

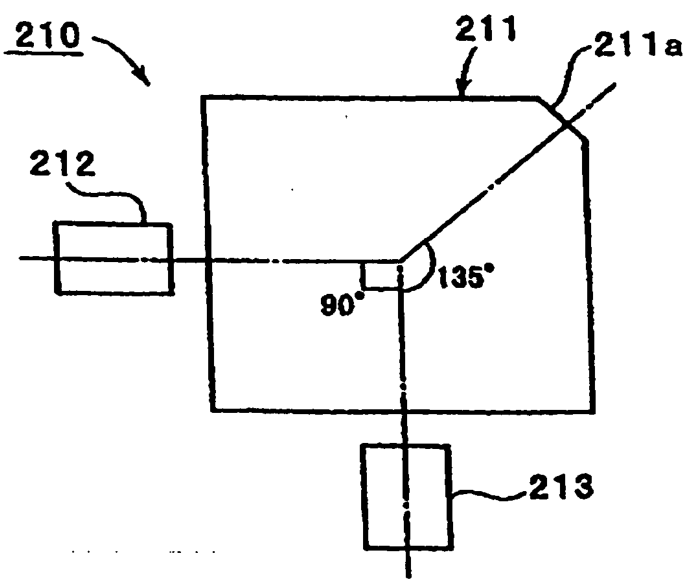
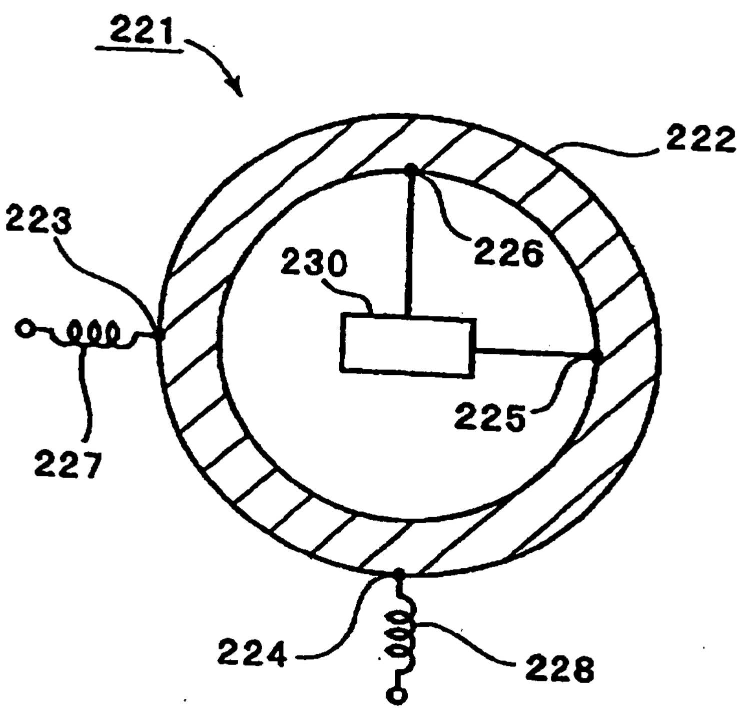


Fig. 50



European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 01 10 1079

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| X | EP 0 509 636 A (LORAL SPACE SYSTEMS INC) 21 October 1992 (1992-10-21) * column 3, line 28 - line 46 * * figures 2B,2C * | 1 | |
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| X | ZHU L ET AL: "NEW PLANAR DUAL-MODE FILTER USING CROSS-SLOTTED PATCH RESONATOR FOR SIMULTANEOUS SIZE AND LOSS REDUCTION" IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES,US,IEEE INC. NEW YORK, vol. 47, no. 5, May 1999 (1999-05), pages 650-654, XP000827467 ISSN: 0018-9480 * abstract * * figures 1,2,6 * | 1 | |
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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| MUNICH | 1 June 2001 | von Walter, S-U |

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